DEVELOPMENT OF HIGH EFFICIENCY GAS - FIRED DOMESTIC WATER HEATER (UP-E-201)

Final Report

By

Modern Times A & M

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SUMMARY

The objectives of this contract were to design, develop, construct and evaluate a prototype high efficiency condensing water heater. The unit was to have a limited input capacity of 60,000 BTUH and be equipped with all necessary safety controls. The supply of combustion air was to be preheated by the exiting flue gases and both were to pass through the wall of the house. The term applied to this style of combustion is "Balanced Flue." All of these objectives have been met.

The performance of the condensing water heater was acceptable from all technical points of view. The steady state combustion efficiency of the system varied between 80% and 110% (based on the lower heating value) with the average being 92%. This variation in efficiency was caused by the variance in inlet water temperature to the condensing coil. As inlet temperatures increased, efficiencies decreased.

The off-cycle and stand-by losses were reduced to being only conduction losses through plumbing and tank walls. These losses represent approximately 7 to 15%, depending upon the amount of insulation present around these areas. Therefore, a seasonal efficiency of between 77% and 85% can be expected from this product. When compared to the seasonal efficiency of a conventional gas-fired water heater of approximately 50%; the improved efficiency of about 30% is quite substantial.

When this 30% in improved seasonal efficiency is applied to a relative pay-back period for an average residential consumption of hot water, the economics for retrofit to an existing installation become questionable. For new installations, the unit's cost is comparable to a conventional water heater and thus appears very attractive.

The retrofit economics are largely due to the fact that residential water heating does not consume as much energy as would be required to make the premium cost of this condensing water heater feasible. The average payback period would be 4 to 7 years. If this unit were to be utilized in a commercial institution where hot water demand is much higher, then the payback period could become quite attractive at less than one year.

SOMMAIRE

Les buts de ce contrat étaient de créer de développer de construire et d'évaluer un prototype de chauffe eau, condensant le gaz de cheminée à haute efficacité. Cet appareil devait avoir un rendement maximum de 60,000 BTUH et il devait être équipé avec toutes les commandes de sécurité nécessaires. La suppléance d'air de combustion devait être préchauffer par les gaz de chiminée et ensemble ils devaient passer à travers le mûr. La terminologie utilisée pour ce genre de combustion est "échappement équilibré." En somme, les objectifs ci-haut mentionnés ont étaient accomplis.

La performance de cet appareil a été satisfaisante sous tous les aspects techniques. L'érat constant du rendement de combustion a varié entre 80% to 110% pour une moyenne de 92%. Cette fluctuation de rendement est dûe à la fluctuation de la temperature de l'eau d'arrivé dans l'échange de chauffage condenseur. Le rendement augmente eu proportion directe avec la temperature d'arrivée.

Les pertes hors du cycle ou durant les périodes d'attente ont été réduites aux pertes de conduction à travers les tuyaux et les mûrs du réservoir. Ces pertes représentent approximativement 7% à 15%, selon la quantité d'isolation entourant ces parties. En conséquent on peut s'attandre à un rendement saisonnier de 77% à 85%. Comparé au rendement saisonnier d'un chauffe eau à gaz d'à peut près 50%, l'amélioration du rendement de 30% est substantielle.

Toutefois quand ce 30% de rendement amélioré est appliqué à une période relative de remboursement pour une consommation moyenne résidencielle d'eau; le remboursement est discutable du point de vue économique.

Ce la est dû au fait que le chauffage d'eau résidenciel ne consomme pas assez d'énergie pour justifier le côut de ce chauffe eau. Le remboursement moyen serait de 4 à 7 ans. Si cet appareil était utilisé dans une institution commerciale ou la demande d'eau chaude est plus grande, la période de remboursement serait d'un an ou moins.

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1.0 INTRODUCTION

The conventional design of domestic water heaters incorporates a 30 to 60 gallon reservoir in order to meet peak usage requirements. The stored water is heated through two surfaces; a) a bottom plate having a shallow cone shape and b) an internal flue, which is baffled in order to restrict excess air. Air is mixed with the fuel in a multiport mixing burner with natural buoyancy providing the draft. Ignition is provided for by a continuous gas pilot preset at about 700 BTUH. The main burner firing rate is usually set at about 1000-1200 BTUH per gallon of storage - a rate which will raise the temperature of the stored water 90°F in about 55 minutes at a 72% recovery efficiency. The 28% loss in a gas-fired heater during the recovery mode is due to stack losses; typical stack parameters are 550°F and 50% excess air (7-8% CO_2) before the draft diverter. Flue losses include as a percent of heat input, about 9% in the form of uncondensed water vapour and 17% as unrecovered enthalpy in the hot combustion products. Conventional chimney design dictates that condensation be prevented.

In addition to the recovery losses, there are also standby losses associated with a storage tank:

1) Loss through insulation
2) Loss through pipe and fittings
3) Loss through exposed metal flue
4) Stack losses of main burner when it is used to reheat water after a cooling period.

Standby losses amount to about 15% of input for electric and 25% for gas-fired water heaters.

In an effort to eliminate these standby losses, European researchers have developed the instantaneous water heater. These are gas-fired heaters installed at the point of use and triggered by a flow switch. However, if an instantaneous gas-fired water heater were built to meet current North American market demands, it would presumably have to incorporate several characteristics:

1) One central unit with a large flue.
2) A burner firing rate of 300,000 BTUH to give a suitable temperature rise at a 5 GPM flowrate which is required for simultaneous draws by 2 major water uses.
3) A provision would have to be made to allow for modulation of the burner since all draws are not equal.
4) A provision would have to be made to allow for hot water to be supplied during the 30 second start-up and stabilization time, i.e. a small 2-5 gallon storage tank.
5) A useful lifetime of 10-15 years would be expected.

A system designed solely upon these criteria would be large, expensive and not cost effective from the consumer's standpoint. Therefore, the design of the system as described within this report combines the positive features of each of the previously mentioned methods of domestic hot water production and improves on them to make a High Efficiency Condensing Water Heater. The resulting unit, illustrated in Figure 1, has a firing rate of 30,000 BTUH and employs a balanced flue design with a secondary heat exchanger to promote condensing of the water vapour in the flue gases.

It is also connected in parallel with a highly insulated storage tank so that peak demands may be easily satisfied without extremely high firing rates. It operates at recovery efficiencies approaching 100% and only loses about 8% in standby losses, thereby yielding a seasonal efficiency in the 90% range.

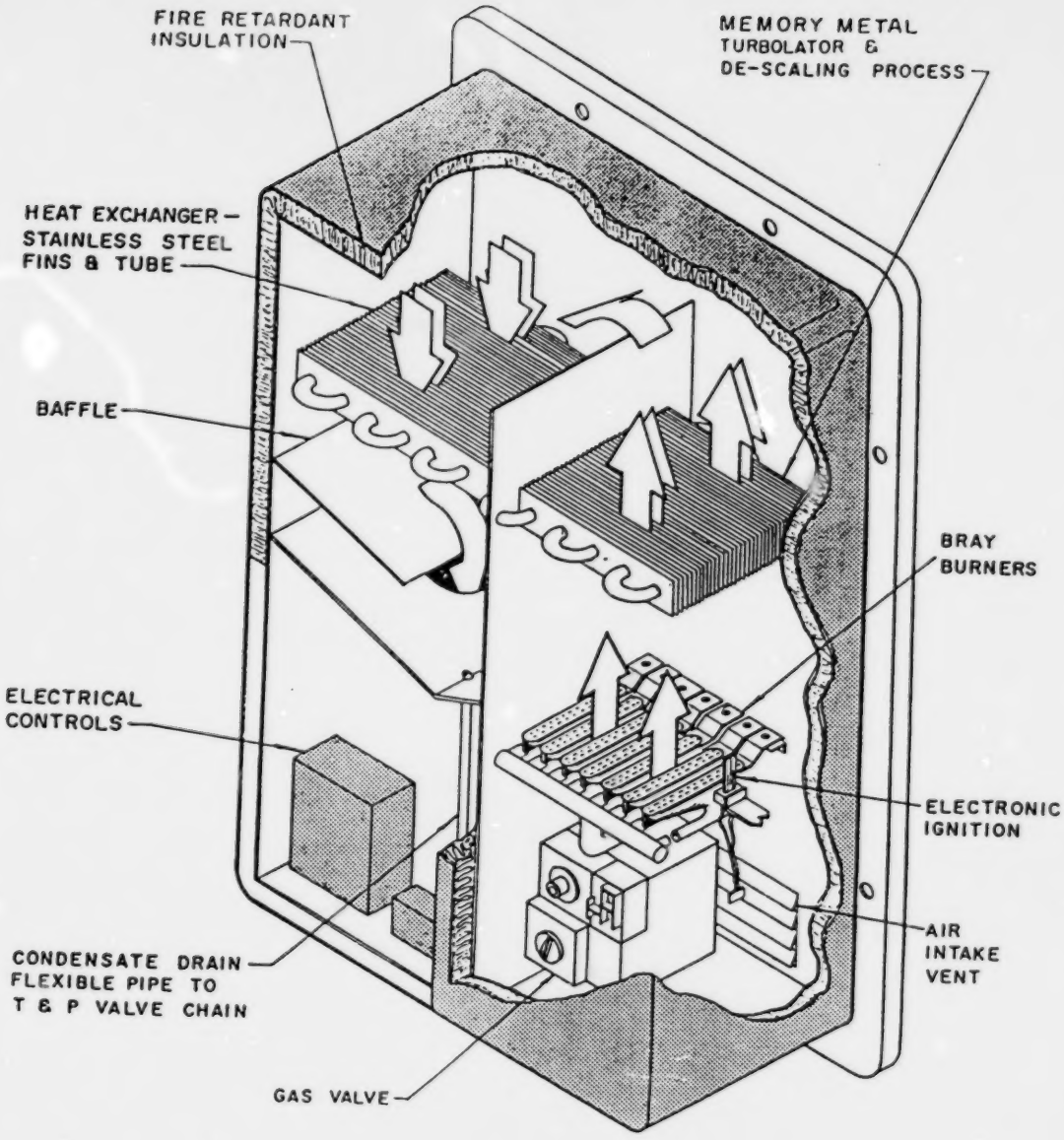


Figure 1.

HIGH EFFICIENCY GAS-FIRED DOMESTIC WATER HEATER

1.1 DESIGN FEATURES

The concept of the boiler was to cool the flue gas to below the dew point, where a considerable part of the water vapour in the flue gas would release its heat of condensation to the incoming boiler water. Consequently, maximum efficiencies would be experienced when inlet water was below 120°F. However, since the water inlet for the boiler is taken directly off of the top of the storage tank, the temperatures are often in excess of 120°F. Therefore, the size of the heat exchangers in the boiler were determined by computation using known data about; flue gas temperature; flue gas flow rate; pressure drop restrictions; water flow rate; water temperature; heat exchanger efficiencies; desired input and desired output. With the basic sizing of the heat exchanger in mind, a review of burner manufacturers of the plan area type revealed the required face area by input requirements. This, combined with flame height tests and static pressure drops through various fin configurations, led to the design and sizing of the present combustion chamber and placement of the heat exchangers over the combustion zone.

Balanced Flue Feature: Simply put, conventional heating systems detract from their already poor efficiency by drawing the air they need for combustion and dilution from the heated air within the house. This situation results in more cold air being drawn into the house to replace that used for combustion and this new air must be heated in its turn, at significant cost and at a significant reduction in the overall system efficiency.

In order to alleviate these problems, this study was aimed at designing a unit which would draw air for its combustion directly from the outside.

A further improvement has been made in that the flue consists of two concentric pipes, with the inner pipe carrying the exhaust gases out and the outer pipe carrying the combustion air in (see Figure 2). The advantage of this arrangement is that the pipe acts as a simple heat exchanger, allowing the incoming air to be preheated by the exiting flue gases. Even though these flue gases have already given up most of their heat in the condensing system, there is still a useful advantage to be gained by this design, further improving the efficiency margin.

Small Size and Versatility: The complete unit, including burner, two heat exchangers and all controls, is extremely compact. The final production configuration will probably not exceed 30"x18"x10" and will mount flush to an exterior wall so that the cooled flue gases can be exhausted conveniently and so that the incoming air can be similarly brought into the unit (see Figure 3).

These dimensions do not consider the 30 gallon storage tank which the water heater is designed to operate with. Due to the high thermal capability of the burner, the average household can operate well with only a thirty gallon unit. This is in contrast to the much larger capacity tank usually required to compensate for the slower recovery ability of electrically heated hot water systems.

Modifications: Preliminary testing of a first prototype revealed excessive temperatures surrounding the combustion chamber and slight heat degradation of the fins on the primary coil surface. A new combustion chamber was designed by providing a copper coil wrap to extract much of the excessive heat in the small combustion chamber. This became the heart of the unit, around which the necessary components and cabinetry were laid out to complete the system.

Figure 3 depicts the installation of the unit, as a hot water heater, as tested. This would represent a typical installation where high efficiency gas water heating was desired. Note that a chimney is not required.

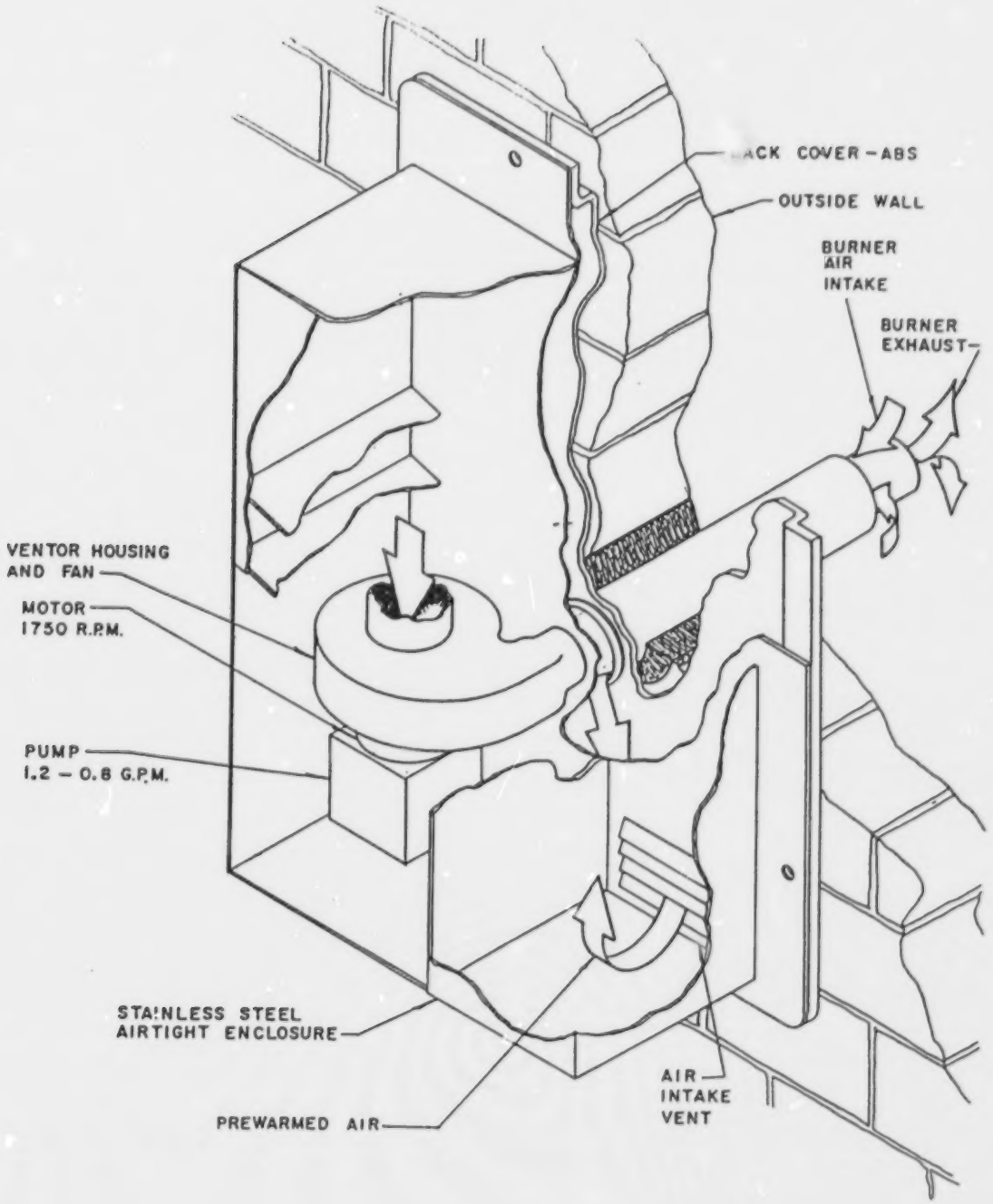


Figure 2.

CUTAWAY DISPLAYING BALANCED FLUE

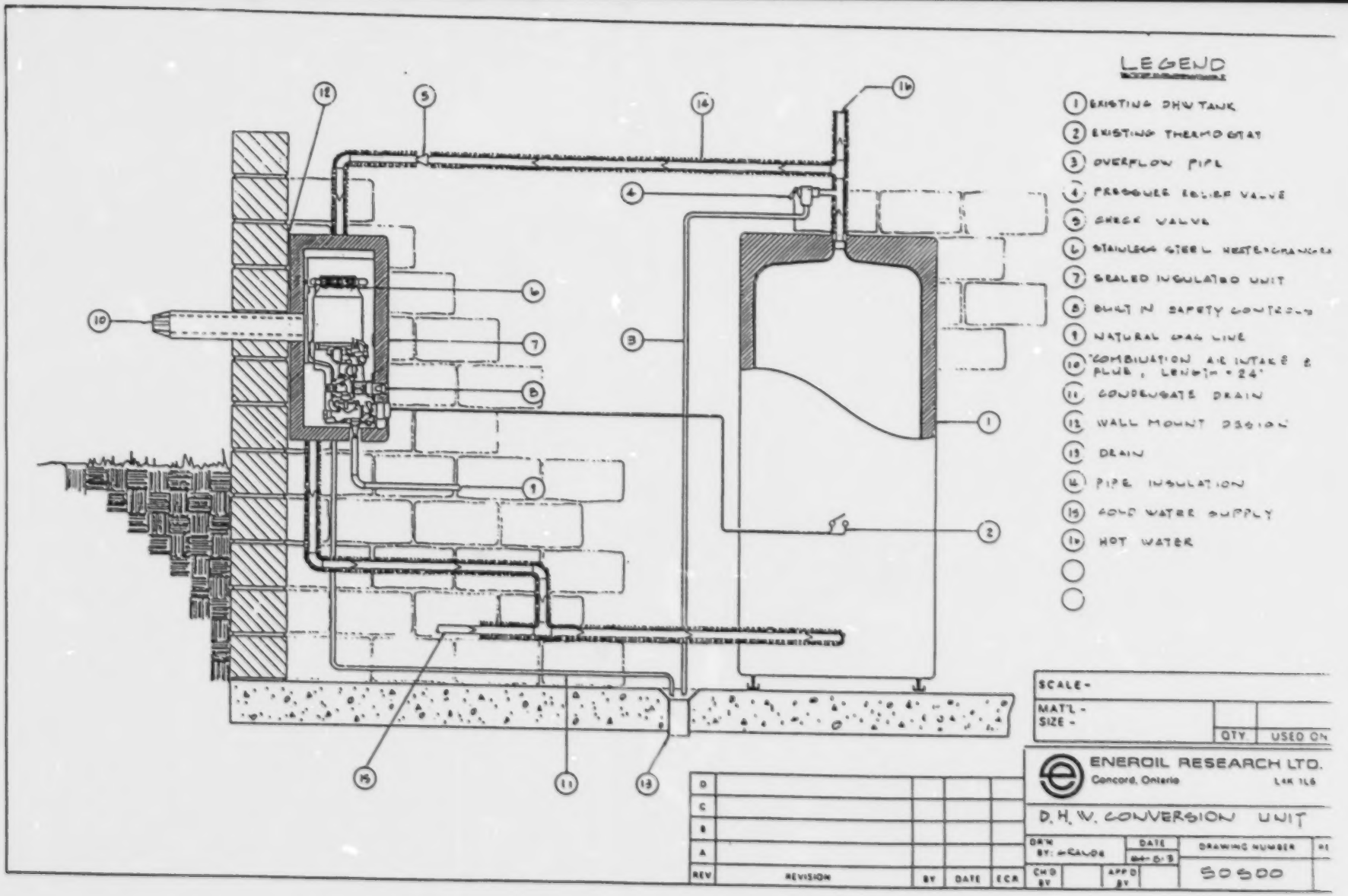


Figure 3.

WATER HEATER INSTALLATION

2.0 TECHNICAL SPECIFICATIONS

2.1 COMPONENT PARAMETERS

Prior to the selection process of the required water heater components, an outline of each component's function and operating requirements was performed. The following is a list of those components and a brief statement of the parameters involved in selecting each one. (See APPENDIX "D" for photographs of components.)

Heat Exchangers: There are two totally different environments (combustion zone and condensation zone) involved in the heat exchange process and consequently there must be a totally different type of heat exchanger for each environment. The primary heat exchanger will not be exposed to condensing gases and therefore should be of maximum heat transfer capability while still being able to withstand the extreme temperatures supplied by the gas combustion process (approx. 2000°F.). The condensing heat exchanger must also be of maximum heat transfer capability but must be resilient to the corrosive environment of condensing flue gases. In addition, both heat exchangers must be lightweight, inexpensive, and provide long lifespans with a minimum resistance to flow.

PUMP: The pump must be operable at temperatures approaching 200°F and be able to provide a constant flowrate of between 0.5 and 2.5 GPM at a head pressure of up to 10 ft. It must also be able to operate at internal pressures of up to 100 psi.

VENTER: The venter must be able to provide a consistent flowrate of 5 to 35 cfm at a high static pressure. It must also be able to survive an environment of condensing flue gases and temperatures approaching 180°F. It must also be small, lightweight and inexpensive.

VALVE: This should be a two-stage valve with total shut-off. It should operate on 24 volts and draw very little current. The ignition system must incorporate flame sensing and provide for automatic ignition. The dimensions of the valve should be as small as possible.

PRESSURE SWITCH: This will be one of the safety devices of the water heater designed to sense air flow through the venter outlet. It should be extremely sensitive in the low pressure area of 0.05" w.c. and be as compact as possible.

TRANSFORMER: Once again compact size is of great importance. The requirements are for a 120V primary to 24V secondary able to supply approximately 20 to 40 VA of power.

HIGH LIMIT: Another safety device to be installed in the hot water outlet of the boiler to sense over 200°F temperatures and temporarily interrupt the power supply to the gas valve. It should be easily installable.

BURNER: The burner must be capable of supplying an even flame and temperature over the entire area heat exchanger. It must also be an efficient burner able to operate at the required output with a very short flame height. The burner material must be heat and corrosion resistant.

2.2 COMPONENT DESCRIPTIONS

The following descriptions of components are based on the actual components which were selected from several alternatives that had previously been identified from various manufacturers. A detailed list of the various manufacturers which were investigated as potential sources is included in APPENDIX "C" (COMPONENT SOURCES).

Burner: The burner being utilized is a seven element Plan Area burner with a single injector venturi manufactured by FURIGAS Inc. The burner measures 5 x 4½ inches in surface area and sets the precedence for combustion chamber and coil sizing. All of the materials used in the burner are stainless steel and therefore are heat and corrosion resistant. This type of burner was selected because of its even heat distribution over a given area and also because of the low, well controlled flame height that is produced.

Heat Exchangers: There are three areas of gas to liquid heat exchange surfaces: The primary coil; the condensing coil; and the combustion chamber itself, which is surrounded by a water tube wrap to extract all available heat. The coil wrap also acts to maintain cooler temperatures throughout the surrounding components and cabinetry as well as preventing excessive primary coil surface temperatures which could cause damage to the fins of that coil.

The primary coil is manufactured by BOHN HEAT TRANSFER and is a finned tube style of heat exchanger. The construction is of 1/2" copper tubes in a 2 row, serpentine configuration inserted into copper fins at 8 fins per inch. This coil is exposed directly to the flue gases and radiant heat of the burner, therefore, the majority (approximately 75%) of the heat is absorbed and transferred to the flow of water in this area.

The condensing coil is also manufactured by BOHN HEAT TRANSFER and is of the same dimensions as the primary coil. It is located directly over the primary coil with a condensate baffle and collection tray installed between the two coils. The construction of this coil is 1/2" copper tubes in a 2 row, serpentine configuration inserted into aluminum fins at 12 fins per inch. The entire coil is

then coated in a special teflon material called BOHN COAT I. This coating makes the coil impervious to external corrosion by condensing flue gases. The flue gas entering this coil is at approximately 500°F and the water flowing through the coil comes straight from the storage tank at about 70°F to 140°F.

The water flow leaves the condensing coil and enters the combustion chamber coil. This is constructed of a copper sheet with 1/2" copper tubing brazed to the surface of it and formed into a box with rounded edges to completely enclose the combustion area and direct hot flue gases to the primary coil. The manufacturing of the integrated combustion chamber with the coil wrap is presently a custom process but production quantities could easily be handled by any sheet metal working plant at a very reasonable manufacturing cost.

Valve and Ignition System: The valve and ignition system components are manufactured by FENWALL INC. They are very compact devices designed for operation at low firing rates. The valve is of the redundant type and is factory set to regulate output pressure to 4" W.C. on natural gas. The valve works in conjunction with an electronic control which serves to sense the flame and produce a sufficient voltage to heat a resistance element for purposes of ignition. In the event of flame failure, the electronic module ceases to allow voltage to flow to the valve thus preventing natural gas from flowing out unignited. The ignition system utilizes a direct hot surface rather than a standing pilot, thereby reducing off-cycle losses. During operation the valve controls gas flow to a single brass orifice which is sized to fire at a rate of 30 MBTUH at 4" W.C.

Pump: The pump which has been selected to circulate the water from the storage tank, through the water heater and back to the tank is manufactured by MARCH MANUFACTURING. It is a pump that is standard throughout the hydronic and solar heating industries. Therefore, it is capable of withstanding temperatures of 250°F continuously and providing a flowrate of 5.3 GPM and a maximum head of 11.6 feet. The pump housing is manufactured out of polysulfil plastic. The impeller is magnetically driven by a 1/25 HP, 115 VAC motor.

Venter: The cooled combustion products are vented through a polysulfil plastic ventor housing. A small polysulfil plastic radial wheel of 3.6" diameter, driven by a 1/125 HP open type 115 VAC motor provides the necessary draft to efficiently evacuate the products of combustion. This venter is very compact, quiet and consumes little power. It is manufactured in the U.S. by TEC AIR INC.

Safety Devices: As stated previously, the ignition system iself incorporates a flame sensing mechanism which shuts the gas off in the event of flame failure. In the event that the tank thermostat should fail or water flow should be restricted, a high limit sensor is mounted in the water line exiting the heat exchanger to prevent the water temperature from exceeding 210°F. There is also a small pressure differential switch mounted in the unit to monitor the exhaust gas pressure and ensure that there is positive, unrestricted air flow. If any of these safety devices are activated, the result will be immediate burner shut down. In addition, there is also an overpressure relief valve plumbed into the DHW system which will allow for pressure relief in case of excess pressure build up.

Appendix E contains copies of the manufacturers' literature pertaining to the major components as described in this section.

3.0 COMBINED SPACE/WATER HEATING SYSTEM

The purpose of the proposed "Combined System" is to utilize the High Efficiency Water Heater as a source of DHW heating as well as provide a primary source of home heating with a back-up system of electric elements incorporated into the forced air-handling unit. It is a well known fact that maximum efficiency is obtained from a combustion device when it is allowed to operate at steady state conditions as uninterrupted as possible. This is the concept of the Combined System. The cyclic losses are greatly reduced by utilizing the Domestic Storage Tank as a thermal buffer for the Forced Air Hydronic Heating System. (See Figure 4 for a sketch of this system.) A description of the system in its three modes of operation follows.

Mode 1: DHW HEATING ONLY (Summer)
During the summer months when there is no demand on the forced air heating system, the solenoid valves which are plumbed into the hot water outlet of the boiler are activated to only allow for water circulation through the DHW storage tank. During this mode, the only device controlling the operation of the boiler is a tank thermostat. When the tank thermostat senses a drop in temperature, the power is switched on to the circulating pump and ignition system thereby allowing the boiler to quickly make up the heat loss from the DHW tank.

Mode 2: HOME HEATING ONLY (Winter)
During the winter months there is a potential for all three modes of operation, but let us first examine the heating only mode. The controlling device in this mode is the room thermostat. This will activate the circulating pump and allow for hot water to circulate through the hydronic coil located in the air-handling unit and back to the DHW tank. The water will be circulating through the boiler

as well, but the ignition will not be energized until the lower tank thermostat senses a drop in temperature. At this time ignition will begin and heat loss will be made up by the boiler.

When the room thermostat is satisfied, the solenoid valves will again isolate the air handler unit from the system and allow for operation as in MODE 1. If the heat loss of the structure is greater than the make-up capacity of the boiler, then a room sensor with a minimum setting will activate the electric auxillary heating elements to assist in bringing the temperature up to the desired setting again.

Mode 3: DHW AND HOME HEATING COMBINED (Winter)
As can be expected, this mode of operation places the highest demand on the boiler combustion unit. The thermal sensor at the bottom of the tank will engage the ignition of the combustion unit and the room thermostat will engage the circulating pump and the solenoid valves. Therefore, water will be leaving the top of the tank at approximately 120-140°F and supplying the domestic demand as well as feeding the inlet to the combustion unit. The outlet from the combustion unit will be approximately 160-200°F and will feed the inlet of the heating coil. The outlet from the heating coil will be approximately 125-160°F and will mix with incoming cold water to the storage tank to produce a mixed temperature of approximately 70-110°F. If this operating mode extends for a sufficient amount of time, the upper tank sensor will activate the auxillary electric element in the DHW Storage Tank. This will assist in maintaining the tank outlet temperature at an acceptable level for domestic use. As soon as the system demand is decreased (either by satisfied room thermostat or cessation of DHW draw) the combustion unit and circulating pump

continue to operate until such time as the lower tank sensor is satisfied. This type of operation eliminates the inefficient short cycling that occurs with most heating systems during times of low to medium load.

The objective of the above system is to spread the demand times over longer periods of time, thereby decreasing short cycling. If the demand period is excessive, then the auxillary elements in the storage tank and air-handler are available to make up the necessary heat losses without interfering with the continuous operation of the boiler. However, during average demand periods, the temperature in the tank will not drop low enough to activate the auxillary element; nor will the temperature in the room drop below the low limit to activate the auxillary heating elements. Therefore, the average situation would see the boiler operating for very long periods of time without shutdown. This leads to a very efficient operating system.

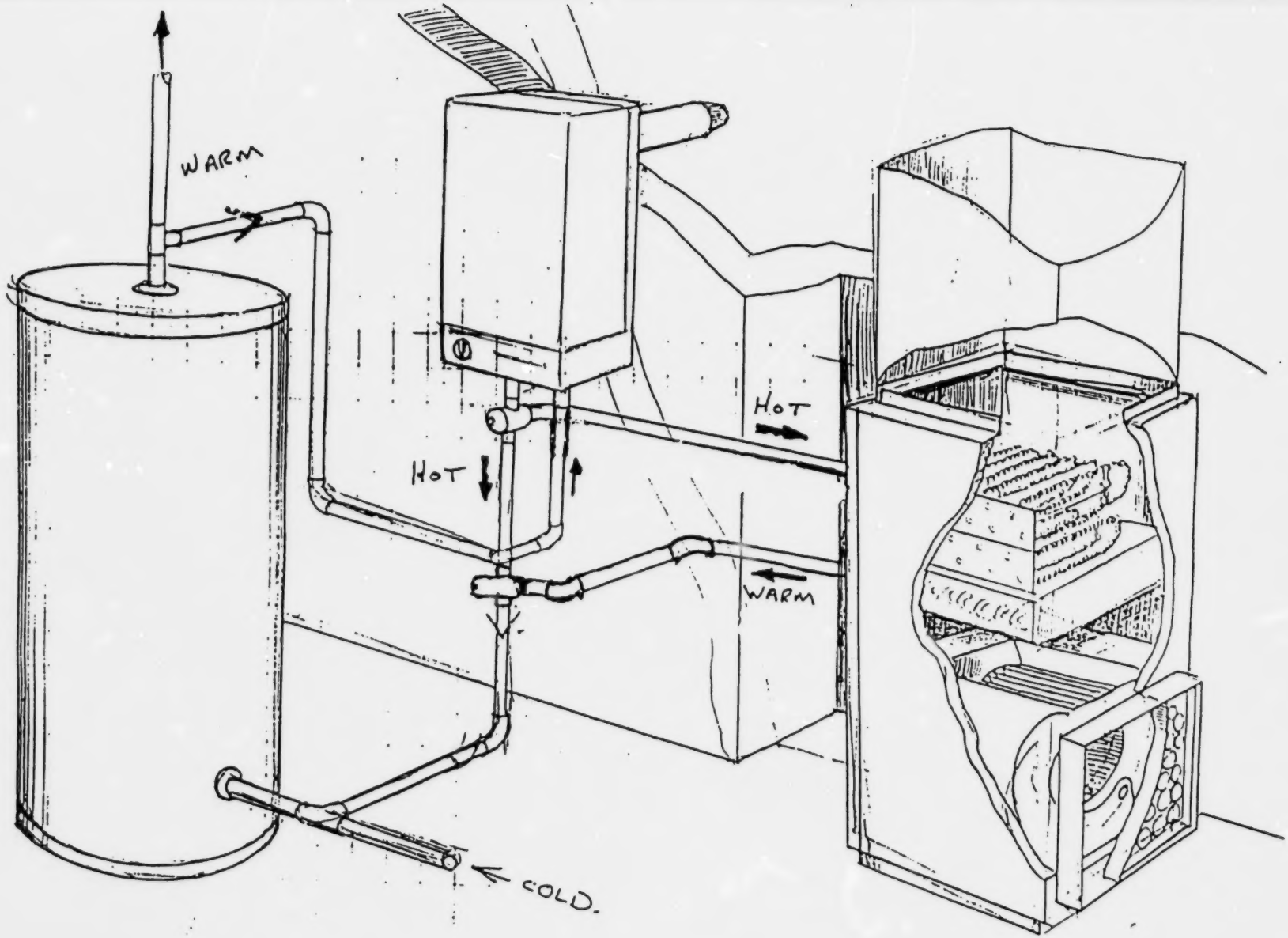


Figure 4.

WATER HEATER INSTALLED AS A COMBINED SPACE/DHW SYSTEM

3.1 APPLICATIONS OF THE COMBINED SYSTEM

The ideal conditions for the installation of the Combined System are those in which a new house has been built with efficiency in mind. This includes large amounts of insulation and small amounts of infiltration with attention being paid to maximize the architectural potential of the building as a heat storing structure. Therefore, the heat losses of the building would be in the 30 to 60 MBTUH range under worst conditions.

Another desirable installation would be one in which the heat losses were relatively low as in a small home or cottage, or in a townhouse or multi-dwelling structure. It would even be conceivable to install a unit as a retrofit to an existing forced air heating system where the original appliance could act as the auxillary and the hydronic coil would be installed in the plenum as an add-on heat pump would be, to eliminate short cycling of the furnace during low demand periods. The added benefit of this would be that DHW heating could be supplied at high efficiency without the addition of a chimney.

3.2 BENEFITS OF THE COMBINED SYSTEM

(1) High efficiency production of hot water for domestic use.
(2) High efficiency production of hot water for home heating.
(3) Stack temperatures low enough to eliminate the need for a chimney.
(4) Eliminates the losses associated with short cycling.
(5) Eliminates off-cycle losses by utilizing a balanced flue feature.
(6) Small, compact unit occupies little space.
(7) Lightweight and self-contained components and controls with minimal field wiring lead to quick and easy installation.
(8) Allows for conversion to high efficiency gas from alternate fuel sources.
(9) Offers ideal heat source for high efficiency designed houses.
(10) Modular design and good accessability allows for easy troubleshooting and servicing.

4.0 OPERATING PROCEDURES AND CHARACTERISTICS

Upon completion of assembly of a fully operational prototype, a series of rigorous tests were carried out to determine the life expectancy, efficiencies and overall operating characteristics of the water heater design.

Natural Gas Flow: A Singer DTM-200 gas meter was used to measure gas flow regulated to 7" W.C. outlet pressure. The flow rate was clocked during operation for short one minute periods and also over the course of several hours to obtain an average firing rate, since firing rates slowly decreased as the injector orifice heated up (See Figure 5). The average firing rate was:

$$29.25 \text{ CFH} \times 990 \text{ BTU/Ft}^3 = 28{,}958 \text{ BTUH}$$

The input variance was seen to be 11% decrease as the unit operated steadily for more than one hour, after which, the input maintained a constant rate. However, for accurate efficiency measurements, it was necessary to maintain a continuous monitoring of gas flow so that proper input rates could be determined for instantaneous moments of operation. This allowed examination of the change in efficiency with time and increasing boiler inlet water temperature.

Water Flow: The circulating pump within the water heater maintains a constant flowrate. However, for test purposes, the flowrates were varied by use of a restricting valve on the pump outlet. This allowed determination of the optimum flowrate for efficiency and temperature rise. For the current design, the optimum flowrate was at about 1.5 GPM (see Figure 6). The unit operated well at this flowrate with an average temperature rise of 30°F and an average operating efficiency of 92%.

The flowrate of 1.5 GPM is also effective in limiting the amount of scale and corrosion on the inside surfaces of the tubes. Scale has a tendency to develop much faster at lower flowrates due to the higher temperatures experienced on the inner walls of the coil. Therefore, the trade-offs that existed between scale build up, temperature rise and efficiency have been well resolved by the current flowrate selection.

Figure 5.

NATURAL GAS CONSUMPTION

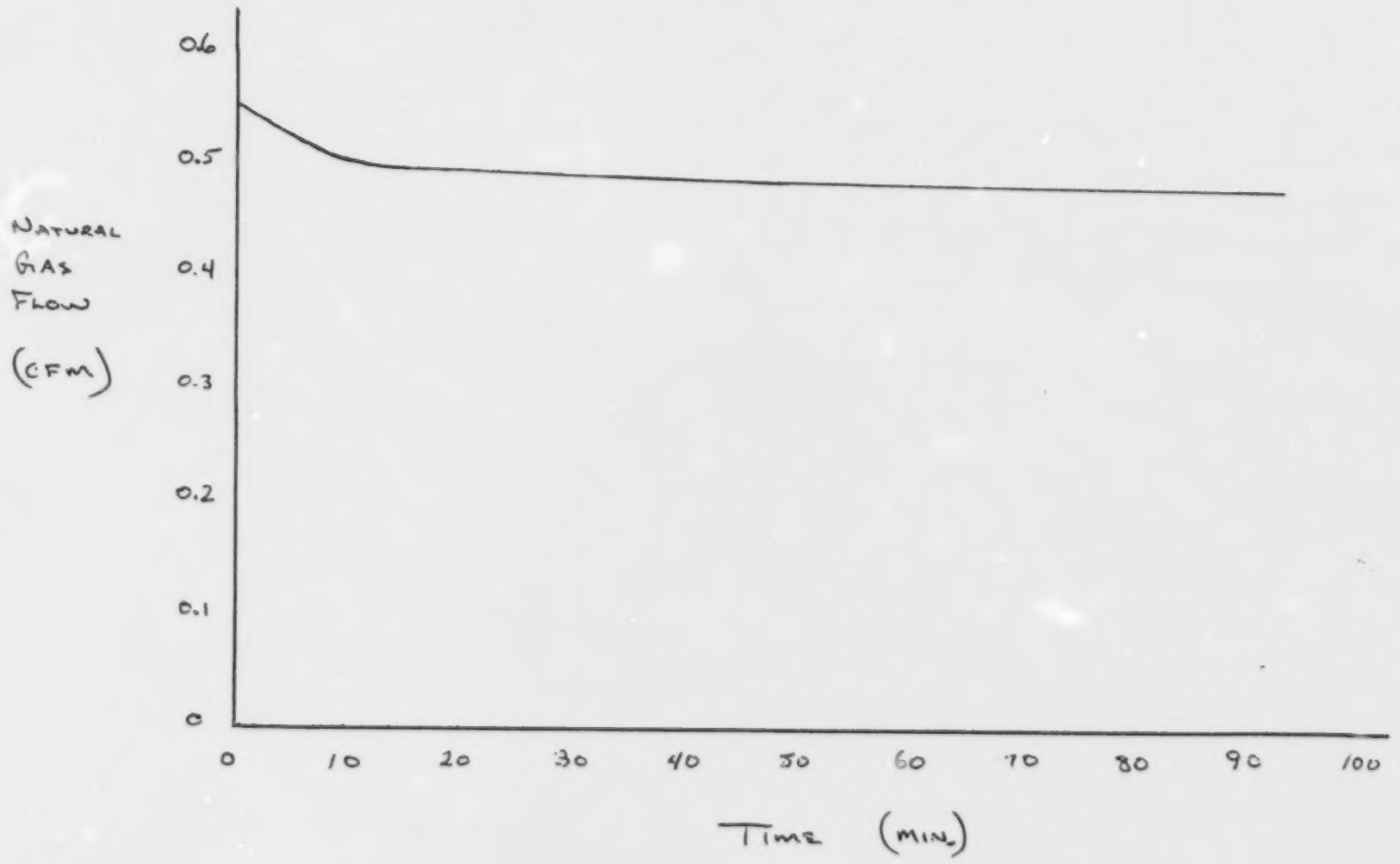
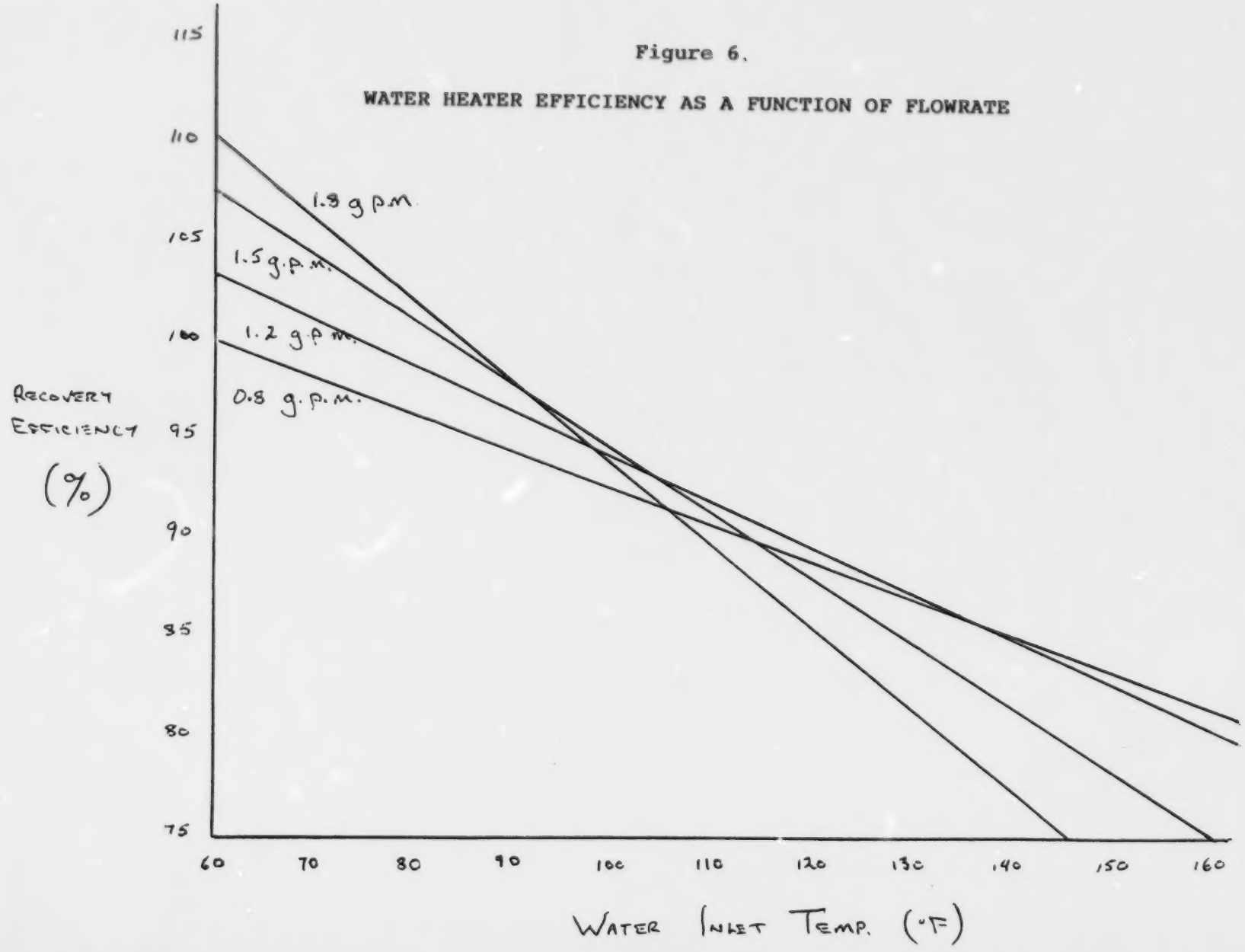


Figure 6.

WATER HEATER EFFICIENCY AS A FUNCTION OF FLOWRATE



4.1 MONITORING SYSTEM

Temperatures were monitored by a Monitor Labs Inc. Data Logger model 9302 using "K" type thermocouples located at strategic locations throughout the unit. Flue gas analysis was carried out using a Beckman model 864 Infrared Analyzer. Natural Gas flow was measured by a Singer model DTM-200 flow meter at 1/10 ft^3 per revolution. Water flow was measured by a Brooks Liquid Flowmeter with a maximum capacity of 3.0 GPM.

Parameters Monitored:

1) TEMPERATURES
   - Water temperatures throughout
   - Flue gas temperatures throughout
   - Radiance temperatures below burner
   - Venter compartment
   - Pump and electrical components
   - External cabinet
   - Ambient air

2) FLUE GAS ANALYSIS
   - % CO_2
   - PPM CO

3) CONDENSATE ANALYSIS
   - pH
   - Quantities produced
   - Temperature

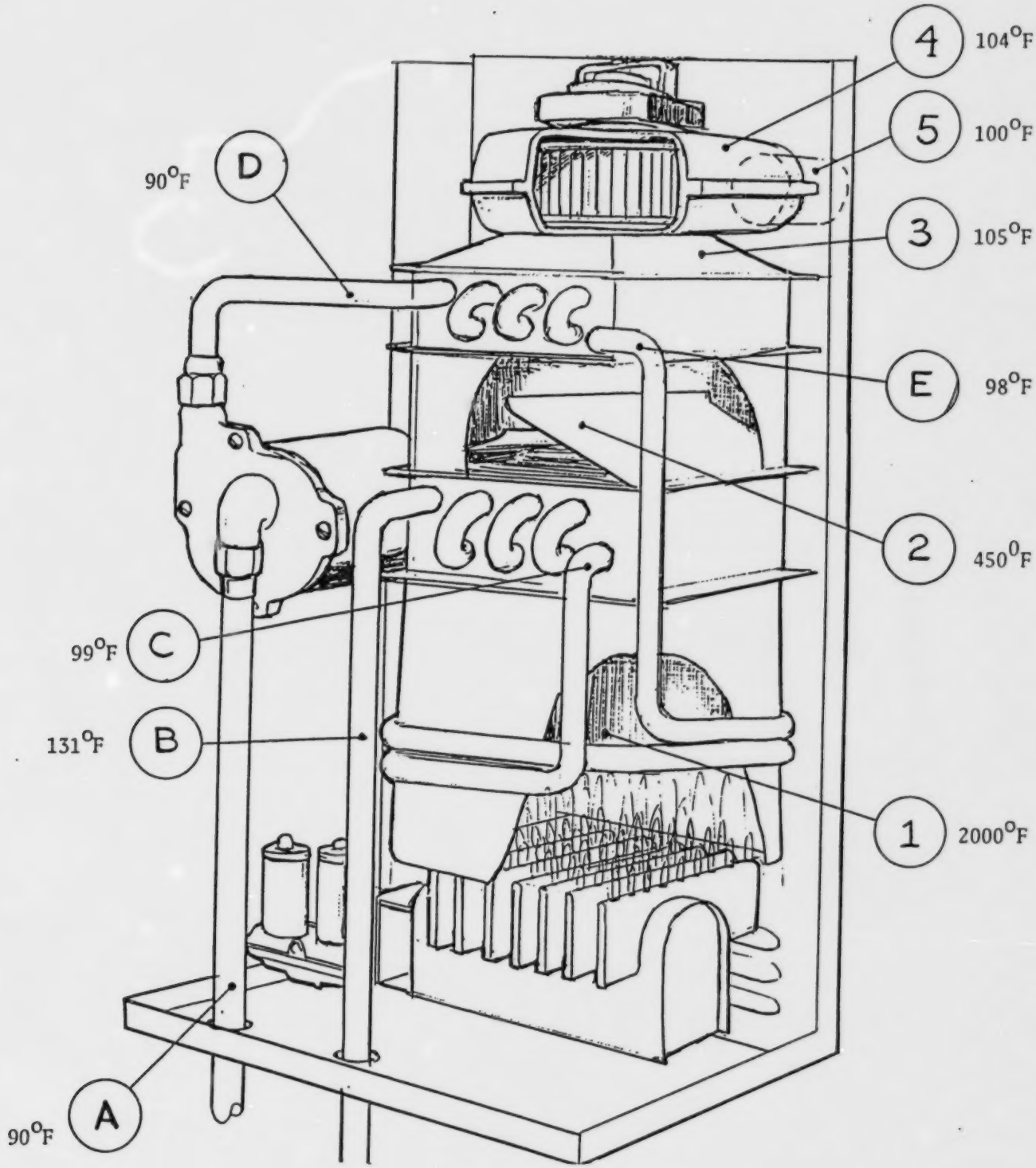
4) NATURAL GAS INPUT
   - Flow rate
   - BTU content (obtained from Consumers Gas)

5) SYSTEM WATER
   - Pressures
   - Flowrates

Actual test results are given in APPENDIX "A".

Figure 7.

WATER HEATER TEST UNIT SHOWING THERMOCOUPLE LOCATIONS



Legend of Thermocouple Locations for Figure 7.

Lettered Locations indicate Water Temperatures

Letter A - inlet to boiler (from top of tank)
Letter B - outlet from boiler
Letter C - entering primary coil from comb. chamber
Letter D - entering condensing coil from pump
Letter E - exiting condensing coil to comb. chamber

Numbered Locations indicate Flue Gas Temperatures

Number 1 - flame temp. in comb. chamber
Number 2 - condensate baffle after primary coil
Number 3 - venter adapter after condensing coil
Number 4 - inside venter housing
Number 5 - outlet approximately 18" from venter

4.2 EFFICIENCY CONSIDERATIONS

In conventional residential water heaters, the flue gas temperatures are such that only the lower calorific value of the fuel is utilized. Consequently, the full heat content of the fuel is not utilized. In the case of stoichiometric combustion of natural gas, the water dew point is about 135°F but condensing usually starts to occur at surface temperatures of approx. 250°F when the contacted surfaces become wet.

In general, the efficiency of a boiler is defined as: the heat given off by the boiler divided by the product of fuel quantity and lower calorific value. Therefore, as soon as condensation occurs, efficiency as defined above will exceed 100% and increase as surface cooling decreases, thus allowing the upper calorific value of the fuel to be reached. To some this may seem like an evasion of the laws of thermodynamics, however, the describing of efficiencies in excess of 100% is merely a convention and is a result of using the lower calorific value of the fuel in calculating the fuel consumption. In this way there is a potential for a maximum efficiency of 111% to be obtained. This number is a result of the ratio between the upper and lower calorific values of natural gas.

The efficiencies calculated in APPENDIX "A" are based on the lower calorific values for Natural Gas.

5.0 TEST RESULTS AND DISCUSSION

All of the efficiencies stated in the test results are heat recovery efficiencies, ie. the instantaneous capacity of the water heater to extract the energy available from the measured fuel input. The calculation for this is as follows:

$$E = \frac{\text{Calculated Energy Imparted to Water}}{\text{Measured Energy of Consumed Fuel}} \times 100$$

$$= \frac{M \times C \times \Delta t \quad \text{(Water)}}{CFM \times 60 \times 990 \quad \text{(Nat. Gas)}} \times 100$$

WHERE: M = GPM x 60 Min/Hr. x 10 lb/gal.

C = 1 BTU/lb/°F

Δt = Boiler Outlet - Boiler Inlet Temp.

CFM = Measured Volume of Nat. Gas

60 = Min/Hr.

990 = Lower Calorific Value of Nat. Gas (BTU/Ft^3)

NOTE: WHEN LOWER CALORIFIC VALUES ARE USED, IT IS POSSIBLE FOR EFFICIENCIES TO EXCEED 100%

Using this method of calculation, an accurate means of examining boiler efficiency is achieved quite simply and can be determined at any time since all of the variables are constantly monitored.

The efficiency of the water heater varied with the inlet temperature of the water (Figure 8). From a cold start of 60°F inlet water, the efficiencies averaged 105%, with a few tests yielding 110%. As inlet temperature increased, efficiency dropped. When inlet water reached 140°F, efficiencies averaged 80%. Under normal residential conditions, the inlet water temperature would rarely exceed 140°F and would average between 100 and 120°F. Operating under these conditions, the steady state efficiency was found to be about 90%.

5.1 RECOVERY RATE

For the purposes of measuring recovery rates, it was necessary to install thermocouples throughout the storage tank so that the individual layers of stratification could be examined. During several tests, the recovery rates were averaged out over the entire storage tank. The result of that was a recovery rate of 0.92°F/Min. for a 40 Imp. gallon storage tank. Calculating the recovery rate from what is known about the temperature rise through the boiler and the flowrate, it is found that:

$$\text{Recovery Rate} = \frac{30°\text{F. Temp. Rise}}{40 \text{ gal}/1.5 \text{ g.p.m.}}$$

$$= 1.125 \text{ °F/Min.}$$

This calculated recovery rate assumes that no losses occur throughout the plumbing system or storage tank. Since the test prototype did not have insulated plumbing, it is expected that some losses would occur there.

When this recovery rate is compared with that of a conventional gas-fired water heater, the benefits can readily be seen. As stated earlier, a conventional tank has a firing rate of approximately 1000-1200 BTUH per gallon of storage to obtain a temperature use of 90°F in one hour. That would mean a 40 Imp. gallon storage tank would require 40,000 to 48,000 BTUH input to obtain such a temperature rise. Proportionately, the boiler firing at 60 to 70% of the required rate for a conventional water heater will perform a similar temperature rise in approximately 20% more time. Therefore, a small sacrifice in recovery time is experienced, but a large savings in energy input is more than adequate to compensate. Moreover, if the condensing boiler were matched against a conventional water heater of similar firing rate, it would be seen that the

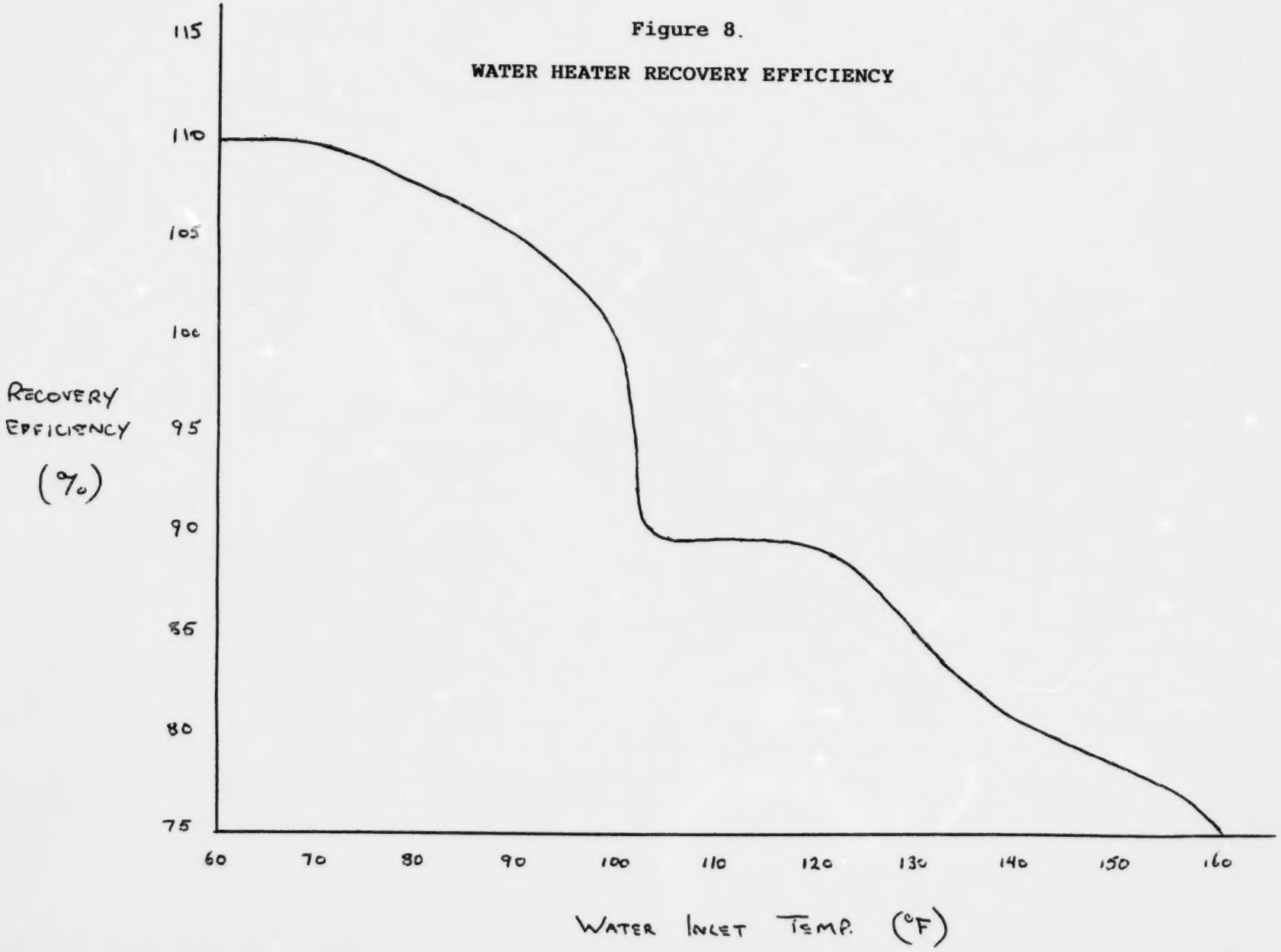
recovery rates of the boiler would in fact be superior to the conventional water heater by approximately 10-20%.

5.2 CONDENSATE ANALYSIS

The production of condensate from the boiler varied with the inlet water temperature. However, from a cold (60°F) tank start-up, the production of condensate was approximately 500 ml until the water reached a temperature where condensing ceased. Operating at a steady state condition of 100°F inlet water temperature, the rate of condensate production was 492 ml/hr. The measured pH content of all condensate produced was 2.8. The average temperature of the condensate produced was 90°F. As inlet water temperatures exceeded 120°F, condensate production dropped off to a rate where the evaporation of the condensate from the coil fins and collection tray was nearly equal to the rate of production. As inlet water exceeded 130°F, there was no visible signs of condensate being liberated from the collection tray. At this point, some condensate began to form in the venter housing and exhaust flue. However, since all materials in the presence of condensate were either plastic or stainless steel, there was no sign of material degradation due to corrosion.

Figure 8.

WATER HEATER RECOVERY EFFICIENCY



5.3 FLUE GAS ANALYSIS

Continuous monitoring of the flue conditions was carried out using a Beckman Infrared Gas Analyzer and a series of K type thermocouples. The flue gas temperatures were affected by inlet water temperatures. Upon cold start-up, the flue temperatures were below ambient and within only 10°F of inlet water temperature. As the water temperatures rose, flue gas temperatures rose accordingly (Figure 9). However, even under adverse conditions, flue gas temperatures did not exceed the allowable safety limit for exposed materials.

A constant monitoring of the CO and CO_2 levels revealed that once steady state was achieved, (within 10 minutes) there was little change in flue gas composition. It was necessary, however, to tune the draft flowrate to optimum levels to maintain clean and efficient combustion. Optimum conditions were obtained with CO_2 levels between 8 and 9% and CO levels barely distinguishable at less than 50 PPM.

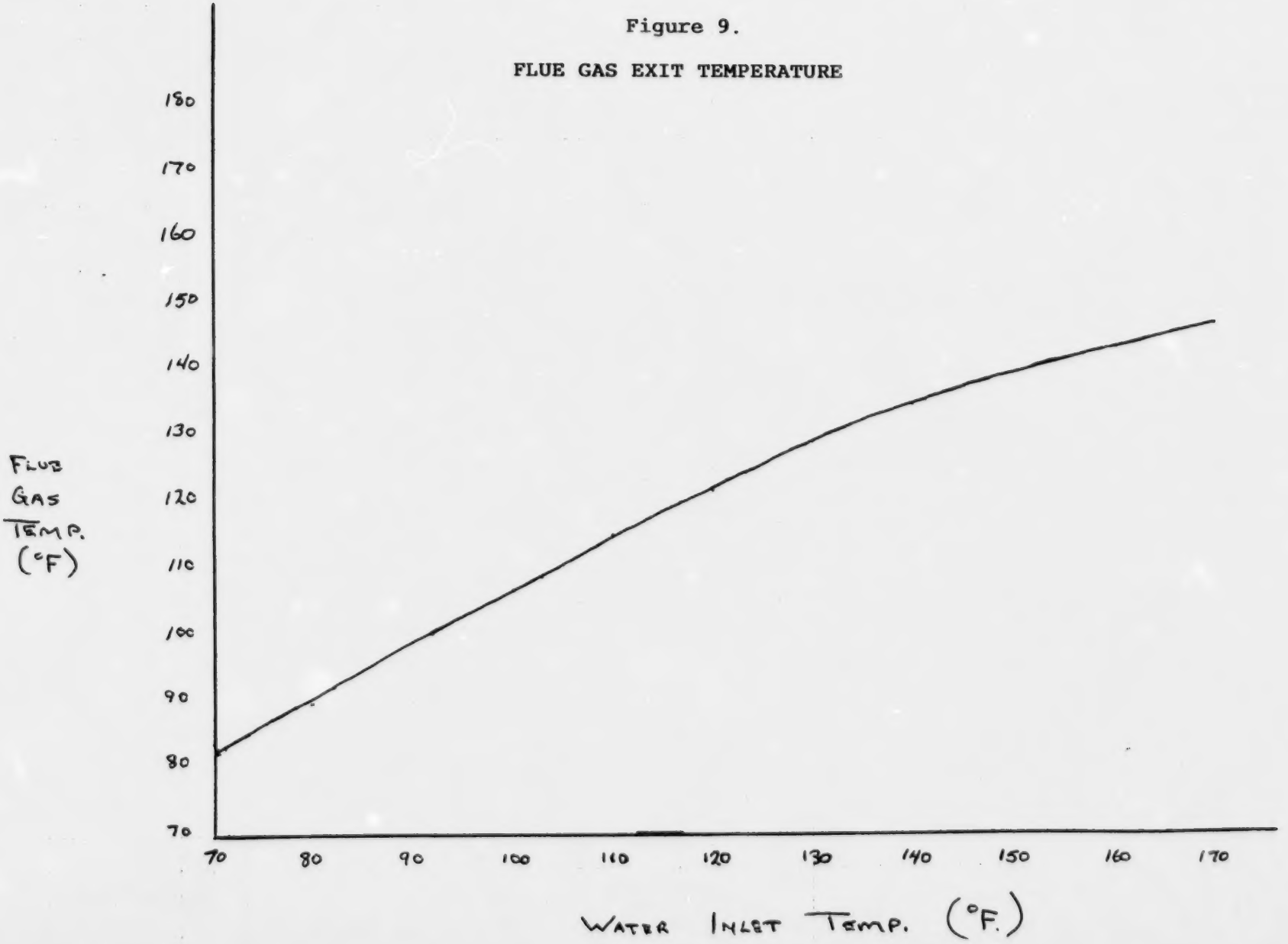
To achieve these levels, it was necessary to maintain a constant static pressure throughout the combustion and venting zones. Tests indicated that optimum static pressures were:

0.0" W.C. over the fire
-0.4" W.C. at venter inlet.
0.38" W.C. at venter outlet.

Static pressures were tuned by means of an adjustable orifice at the outlet of the venter. Once the orifice was set for a given firing rate and vent length, it was unnecessary for any further adjustment to take place. Throughout rigorous cyclic testing, the unit did not require any adjustment and flue gas products remained acceptable.

Figure 9.

FLUE GAS EXIT TEMPERATURE



5.4 OVERFIRE AND UNDERFIRE TESTS

These tests were performed as part of the requirements set out by the Canadian Gas Association for gas-fired appliances. The unit must perform safely and satisfactorily under set input variations. During the required over-fire test, the unit must be able to support proper combustion at a 12.5% increased manifold pressure. During the underfire test, the unit must ignite properly and not experience flame flashback at decreased manifold pressure. The water heater successfully completed these tests with the CO content approaching the limit of allowance during overfire testing. There were numerous other tests that CGA mandates for certification that were satisfactorily completed. Therefore, the design and operation of the water heater is such that it could very well be successfully taken through a CGA certification procedure.

5.5 CORROSION ANALYSIS

During the six months of cyclic and life cycle testing, the water heater was operated continuously at severe and worst case conditions, ie. extended operation at high limit temperatures; sudden and extreme inlet water temperatures; low water pressure conditions; hard water conditions; extended operation at low water inlet temperatures; and restricted flowrates.

Upon completion of this rigorous testing, each heat exchanger was cut and disassembled for visual examination for any signs of corrosion or fatigue. The primary coil (copper fin and tube) showed no internal corrosion but some signs of external oxidation due to condensation formed during continuous low inlet water temperature tests. Some surface oxidation was also visible on the inside surfaces of the

combustion chamber due to condensate dripping down from the primary coil. The burner surfaces were also affected by condensate dripping off of the primary coil but since the burner material is of stainless steel, no oxidation took place. Small mineral deposits were left behind but did not affect burner operation. The tertiary coil (teflon coated aluminum fin, copper tube) showed no signs of corrosion or surface oxidation other than the rust coloured sediment which was left by the venter inlet adapter. Unfortunately, this adapter had to be constructed out of galvanized sheet metal at the time of prototyping and thus was subject to corrosion. This part has been specified to be constructed out of either stainless steel or plastic on future prototypes. The ideal situation would have the adapter as a complete molded assembly with the venter housing and thus decrease the number of separate components involved in the manufacturing process.

The remainder of the surfaces in contact with the flue gases are constructed of plastic and therefore impervious to corrosion. The condensate collection tray is constructed of stainless steel and drains through a plastic fitting and tube and thus also resistant to severe corrosion. However, the weld seams of the stainless tray did exhibit early signs of oxidation and once again mineral deposits were present in this area. The presence of oxidation on the weld seams was due to the selection of weld material. Future prototypes should be sealed by silver solder in this area and should therefore resist corrosion. There were no other signs of corrosion, oxidation, degredation or fatigue anywhere throughout the unit. APPENDIX "D" contains a photographic record of the unit before and after the test program.

6.0 MANUFACTURING ANALYSIS

The condensing water heater was designed with ease of manufacturing in mind. The arrangement of components within the cabinetry is layed out in a fashion which is suitable for efficient aeesmbly. The cabinetry itself is very straight forward in design and can be punched out of sheet metal quickly and inexpensively. Perhaps the most complex items to be manufactured are the condensate baffle and the combustion chamber. The stainless steel condensate baffle is an intricate item requiring precise cuts and bends, as well as watertight welds. Therefore, special equipment is required to do this type of accurate work on stainless steel in a manufacturing endeavour.

The other item of concern is the combustion chamber which being a custom made item requires precision and accuracy in manufacturing. However, since the material of construction is copper, the workability is much better than it would be for stainless steel. We have recommended a dip coating process for the combustion chamber to eliminate oxidation due to condensation. This dip would be performed after the entire chamber has been assembled, including the copper tube wrap. The coating material would be of a tin/lead base and applied in a liquid state by means of heat application. This is an expensive process on an individual basis, but becomes cost effective as volumes reach a manufacturing plausability level.

The manufacturing of these parts and the assembly within the water heater cabinet is a process which would be best performed by a dedicated assembly line. Piece parts and purchased parts would be supplied to the persons on the line and installed according to an established order of assembly.

The completed product would then be tested for electrical consistency and pressure tested for water-tight integrity. Hydrostatic tests would be performed at a pressure of 300 p.s.i. and upon successful completion of these tests, the unit would be prepared for packaging.

The total length of time that each unit should be on the assembly line is approximately 1.5 hours plus another 0.5 hours for piece part manufacturing. Therefore, a total manufacturing time of 2.0 hours has been calculated for the purposes of realistic product costing. The majority of the costing is incurred by the purchased part components; that being a total of $320.00. The cost of assembling, testing, packaging and distributing the unit is another $60.00 to $80.00. That represents a cost of $380.00 to $400.00 per unit to manufacture the water heater. Installation and water storage tank costs would be in addition to these figures (Table 1).

Table 1

HIGH EFFICIENCY
WATER HEATER
COST ANALYSIS

Component	Cost $CDN (1986)
Pump	55.00
Burner	12.00
Valve & Orifice	22.00
Ignition System	80.00
Power Venter	30.00
Heat Exchanger Coil	40.00
Combustion Chamber (inc. coil wrap)	8.00
Condensate Baffle	7.00
Energy Cut-Off	4.00
Transformer	10.00
Air Pressure Switch	7.00
Wiring	2.00
Cabinet & Fabricated Parts	30.00
Transition to Venter	3.00
Plumbing & Fittings	3.00
Cartoning	5.00
Labeling	1.00
Total Parts	$322.00
Assembly Labour	38.00
15 % Profit Margin	50.00
Product Total	$410.00
Estimated Installed Cost to Homeowner	$800.00

7.0 CONCLUSIONS

A prototype High Efficiency Condensing Water Heater has been built which meets the design objectives for efficiency and performance. The steady state operating efficiency of the unit is on average 20% better than a conventional gas-fired water heater of equivalent capacity. Additionally, there is a potential to increase this further by maintaining a cooler inlet water temperature. If inlet water temperatures could be kept to a maximum of 120°F, then efficiencies (based on lower heating values) of 95 to 100% could be consistently realized. To achieve this, it would be necessary to extract the inlet boiler water from the bottom of the tank and circulate it back to the middle or top of the tank. Unfortunately, this would result in excessive stratification and incomplete heating of the entire storage tank. An alternative to this could be the utilization of a coil-in-tank heat exchanger with a counterflow circulation of water in a closed loop system, similar to that of a commercial boiler used to supply DHW. However, this type of a system requires an expansion tank, a makeup water system, additional valves and a highly insulated tank containing a copper heat exchanger coil resulting in much higher installation costs. In summary, the current water heater represents a compromise of design and cost to yield a relatively high efficiency unit at a reasonable cost.

The mechanical design of the unit is efficient and compact. All of the components within the cabinet are well integrated with one another and perform their functions well. The design flowrate is suited to the desired temperature rise given the existing inputs. From over fire test results, it appears that a potential exists to increase the firing rate by as much as 50% with only minor modifications to the existing design. This higher input could be offered as an alternate product in the hydronic heating market for space heating in low heat-loss dwellings.

Insofar as performance is concerned, the unit is judged acceptable. The flue gas temperatures and emissions are within safety limits; the stand-by losses have been decreased by eliminating off-cycle stack losses; the design meets C.G.A. standards; seasonal efficiencies are 25 to 35% better than conventional gas-fired water heaters and the recovery rates are still acceptable by North American standards.

The unit has been designed with ease of manufacturing and serviceability in mind. The materials selected adequately resist corrosion and provide product longevity. One possible area for improvement is the combustion zone where some condensate dripping has occurred from the primary heat exchanger. This has led to some surface oxidation within the combustion chamber and under the burner.

Based on an economic analysis, the cost of manufacturing the water heater is considerably higher than anticipated. The cost to the consumer will reflect that premium cost resulting in a longer payback period. The result of a longer payback period is a lower consumer interest in the product. Therefore, the question of the product's economic viability is in question. From the standpoint of a new housing product, the viability is greatly improved since the necessity for a chimney is eliminated, thus putting the installation cost on par with a conventional gas-fired water heater. However, as a retrofit unit, the costs become less favourable with a payback period of between four and seven years.

APPENDIX A

Test Results

TEST A

Static Conditions:

Ambient air temperature = 69.4°F
Gas BTU content = 990 BTU/FT³
Water flow rate = 2.20 US GPM

Time (min.)	Water Inlet(°F)	Water Outlet (°F)	Flue Gas Outlet (°F)	CO_2 %	CO PPM	Efficiency %
1	73.5	101.6	83.5	7.7	Trace	98.9
2	74.6	102.7	84.8	"	"	98.9
3	76.0	103.6	85.9	"	"	97.2
4	76.7	103.9	86.9	"	"	95.8
5	77.8	105.7	87.7	"	"	96.1
10	83.0	109.7	92.3	"	"	94.0
15	87.9	113.4	96.5	"	"	89.8
20	92.5	117.2	101.1	"	"	87.0
25	96.9	121.6	105.1	"	"	87.0
30	100.5	125.5	107.8	"	"	88.0
35	105.1	128.8	111.0	"	"	83.5
40	109.7	133.0	115.1	"	"	82.0

TEST B

STATIC CONDITIONS:

Ambient air temperature = 69.4
Gas BTU content = 992 BTU/FT^3
Water Flow Rate = 1.8 US GPM

Variables:

Time (min.)	Water Inlet(°F)	Water Outlet (°F)	Flue Gas Outlet (°F)	CO_2 %	Input (BTUH)	Efficiency (%)
2	69.2	106.9	83.0	8.8	32,700	103.7
6	73.5	110.6	86.7	"	32,700	102.0
10	78.4	115.0	90.9	"	32,400	101.6
14	82.3	118.7	94.3	"	32,000	102.3
18	87.0	122.5	98.0	"	31,600	101.0
22	90.6	123.5	100.9	"	31,400	94.2
26	94.3	127.3	104.4	"	31,300	94.8
30	98.4	130.9	107.6	"	31,200	93.7
34	101.3	133.4	106.8	"	31,200	92.5
38	105.1	136.4	110.5	"	31,100	90.5
42	108.6	139.3	113.4	"	31,000	89.0
46	112.2	142.7	116.4	"	29,900	91.7
50	115.8	145.4	119.1	"	29,900	89.0
54	120.7	150.0	122.9	"	29,800	88.4
60	124.4	153.3	125.7	"	29,600	87.8
64	127.5	156.0	128.3	"	29,400	87.2
68	130.3	158.6	131.0	"	29,200	87.1

TEST C

STATIC CONDITIONS:

Ambient air temperature = 70.7
Gas BTU content = 990 BTU/FT^3
Water Flow Rate = 1.2 US GPM

Variables:

Time (min.)	Water Inlet(°F)	Water Outlet (°F)	Flue Gas Outlet (°F)	CO_2 %	Input (BTUH)	Efficiency (%)
2	67.3	120.7	82.4	9.2	31,000	106.7
4	68.8	119.5	83.4	"	30,500	99.7
6	70.9	120.5	84.7	"	30,000	99.1
8	73.4	121.9	86.9	"	29,800	97.6
10	75.2	123.5	89.0	"	29,200	99.1
16	81.2	128.3	94.2	"	29,000	97.3
20	84.8	131.6	97.3	"	28,800	97.4
26	90.6	136.6	102.0	"	28,800	95.8
30	93.9	140.0	104.9	"	28,700	96.3
36	99.1	144.8	109.1	"	28,600	95.8
40	103.2	147.9	112.0	"	28,400	94.4
46	108.1	150.4	115.4	"	28,200	90.0
50	111.6	150.7	118.6	"	28,200	83.1
56	116.6	155.0	123.1	"	28,200	81.6
60	119.3	158.0	125.9	"	28,200	82.2
80	133.5	170.3	136.5	"	28,200	78.2

TEST D

STATIC CONDITIONS:

Ambient air temperature = 66.8
Gas BTU content = 992 BTU/FT^3
Water Flow Rate = 1.2 US GPM

VARIABLES:

Time (min.)	Water Inlet(°F)	Water Outlet (°F)	Flue Gas Outlet (°F)	CO_2 %	Input (BTUH)	Efficiency (%)
2	71.0	122.8	83.7	9.1	31,840	97.6
4	73.3	124.8	85.8	"	31,540	98.0
6	75.3	126.3	87.5	"	31,360	97.6
8	77.4	128.4	88.4	"	31,360	97.6
10	79.6	130.2	90.2	"	30,830	98.4
12	81.5	131.5	92.5	"	30,850	97.2
14	83.2	133.3	94.2	"	30,360	99.0
16	84.9	135.3	99.6	"	30,800	97.8
18	87.0	137.0	97.0	"	30,800	97.4
20	89.2	138.5	98.6	"	30,600	96.7
22	90.9	140.7	100.0	"	30,050	99.4
24	93.3	139.7	101.2	"	30,600	91.0
26	94.8	141.0	102.5	"	30,600	90.6
28	96.9	143.6	104.1	"	30,600	91.5
30	98.1	144.6	105.5	"	30,600	91.1
32	100.3	147.0	107.0	"	30,600	91.5
34	102.0	148.3	108.4	"	30,100	92.3
36	104.0	148.7	110.1	"	30,350	88.4
38	105.0	150.4	111.0	"	30,300	89.9
40	107.4	151.9	112.8	"	30,300	88.1
42	108.6	153.7	114.3	"	30,500	88.7

44	110.9	155.9	115.6	"	30,100	89.7
46	112.7	156.0	116.7	"	30,050	86.5
48	114.9	158.0	118.1	"	29,500	87.7
50	116.2	159.5	119.5	"	29,750	87.3
52	117.9	161.0	120.7	"	29,500	87.7
54	119.3	162.3	121.6	"	29,500	87.5
56	121.2	164.3	122.9	"	29,700	87.1
58	122.5	164.9	123.9	"	29,500	86.2
60	124.4	167.0	125.4	"	29,500	86.6
62	126.1	167.3	126.9	"	29,500	83.8
64	127.6	168.7	127.3	"	29,500	83.6
66	129.4	170.0	128.4	"	29,500	82.6
68	131.0	171.3	129.4	"	29,500	82.0
70	132.3	172.7	130.6	"	29,500	82.1
72	134.1	174.4	131.8	"	29,500	82.6
74	135.6	175.8	133.0	"	29,300	82.3
80	138.0	178.6	134.4	"	29,200	83.4
90	146.0	184.8	136.8	"	29,200	79.7
100	153.6	192.6	139.0	"	29,200	80.1
120	168.2	206.7	148.8	"	29,200	79.1

APPENDIX B

Technical Calculations and Diagrams

This section contains the technical calculations and sketches associated with the development work of the Water Heater to attain the final prototype level as described within this report.

CALCULATIONS:

1. Pump Sizing - Calculating flowrate for variable temp. rises.

Input = 31 MBTUH

Inlet temp. = 60°F min.

Inlet temp. = 160°F max.

Outlet temp. = 200°F max.

Therefore temp. rise = 100°F to 40°F

Mass Flowrate = 31,000/100 to 31,000/40 lbs/hr

= 310 to 775 lbs of water per hr

= 31 to 77.5 imp. GPH

= 0.52 to 1.3 imp. GPM (assuming 100% efficiency)

Actual flowrates should be approx. 20% greater assuming that heat transfer efficiency of the coil is approx. 80%.

Therefore, flowrates should be selected between 0.8 and 1.6 imp GPM.

2. Coil Sizing - Calculating CFM across coil.

Input = 30,000 BTUH

Therefore, approx. 30 CFH of gas required = 0.5 CFM

Combustion Air required @ 10:1 ratio of AIR:GAS = 10 x 0.5 = 5.0

Total Flow = 5.0 + 0.5 = 5.5 CFM for Stoichiometric Combustion

Size for 6.5 to 7.5 CFM since 20% excess air is required for clean combustion, free of CO.

Note: This value should not be used in selecting venter capacity. Venter should be sized at a capacity that easily maintains at least double this flowrate and has static pressure capabilities that will overcome any forseeable levels of combined inlet and outlet static pressures that may be experienced under worst conditions. Therefore, a high static, low CFM venter should be selected.

3. Calculating Burner heat capacity per unit area:

Total capacity required = 30,000 BTUH

Maximum Face Area of Burner = 6" x 6" = 0.25 ft^2

Minimum Face Area of Burner = 4" x 5" = 0.14 ft^2

Capacity per unit area = 30,000/0.25 to 30,000/0.14

= 120,000 to 214,000 BTUH per ft^2 burner

Therefore, select Plan Area Burner in this range capability.

4. Calculating the unit capacity of the appliance:

Input = 30,000 BTUH

Water temp. rise = 50°F

Face Area = 0.175 ft^2 (as selected)

Unit Capacity = 30,000/(0.175 x 50)

= 3429 BTUH/ft^2/°F

TEST OBSERVATIONS:

1. Flue Gas temp. entering coil = 1800°F (primary)
   Flue Gas temp. entering coil = 450°F (secondary)
   Water temp. entering coil = 60 to 140°F (primary)
   Water temp. entering coil = 70 to 150°F (secondary)

2. Draft Observations:

Operates smoothly and efficiently at following conditions.

Pv = 0.15 to 0.20 in. W.C.

Ps = 9.85 in W.C.

Pt = 10.1 to 10.15 in. W.C.

3. Flue Gas Analysis:

During operation when condensing occurring.

CO_2 = 9.5%

CO = 10 to 25 PPM

During operation when condensing not occurring.

CO_2 = 9.1 to 9.2%

CO = 1 to 15 PPM

4. Recovery Times:

For a temp. rise of 20°F = 18.2 min.

For a temp. rise of 50°F = 45.5 min.

For a temp. rise of 100°F = 94.5 min.

Above temp. rises taken at input of 31.8 MBTUH

5. Flame temp. of Natural gas:

at tip of blue center = 2200°F

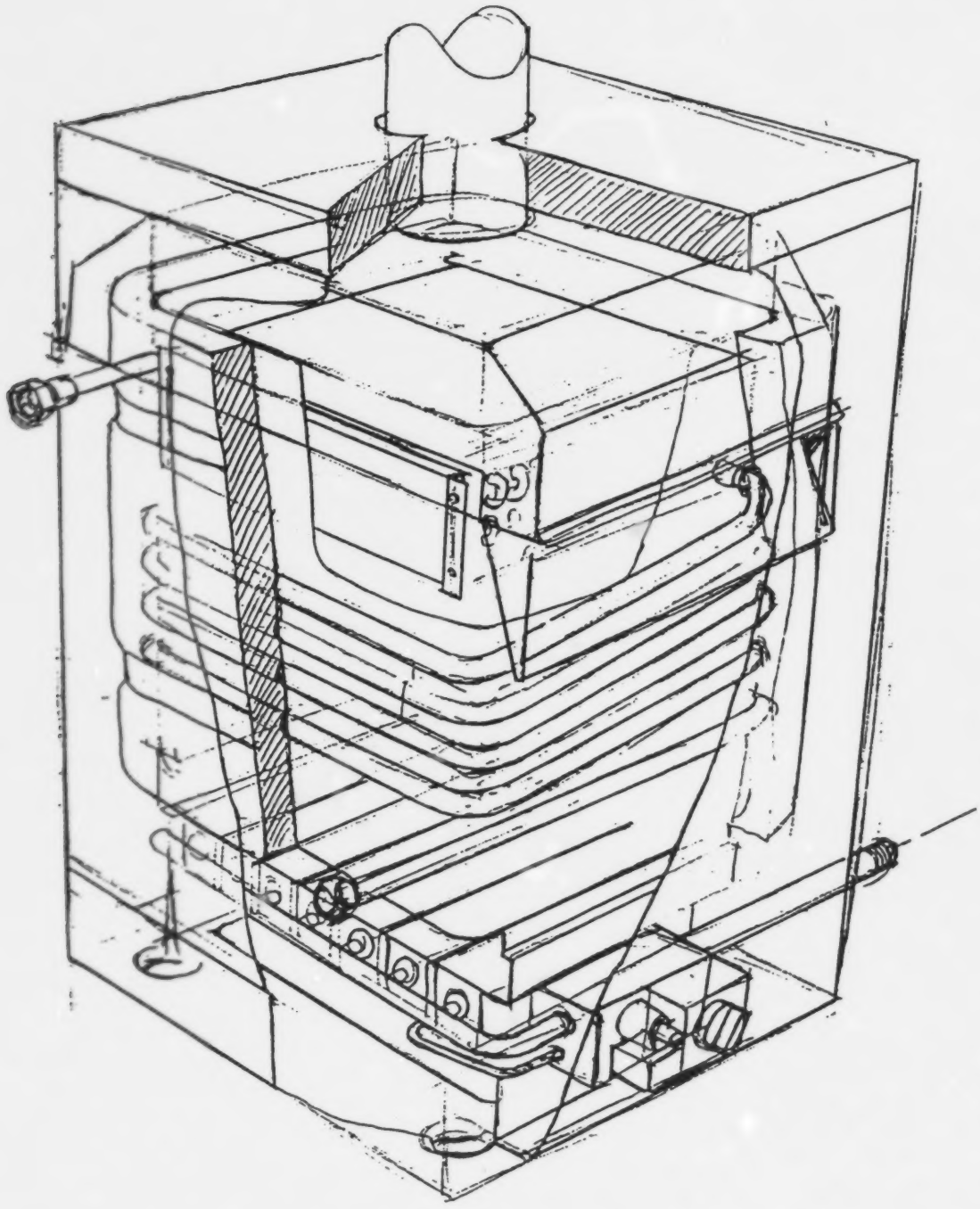
at tip of blue exterior = 2100°F

at tip of yellow flame = 2000°F

For temp. seen by Primary Coil, see the following grid pattern. These temp. are measured at a height of 3" above the flame or 5" above the burner.

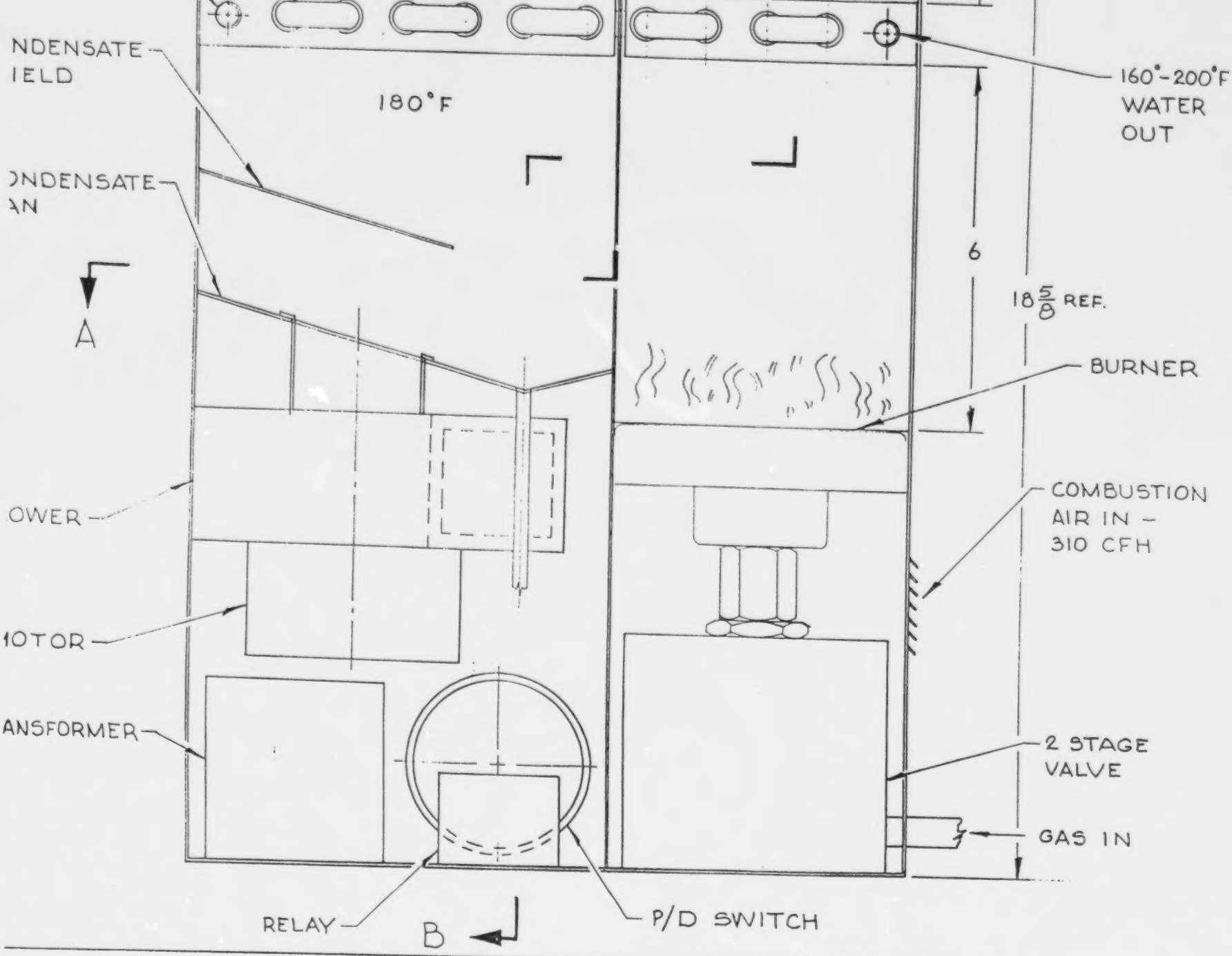
360	990	1800	1050
345	1100	2000	1030
400	1150	1880	900
600	930	1010	630

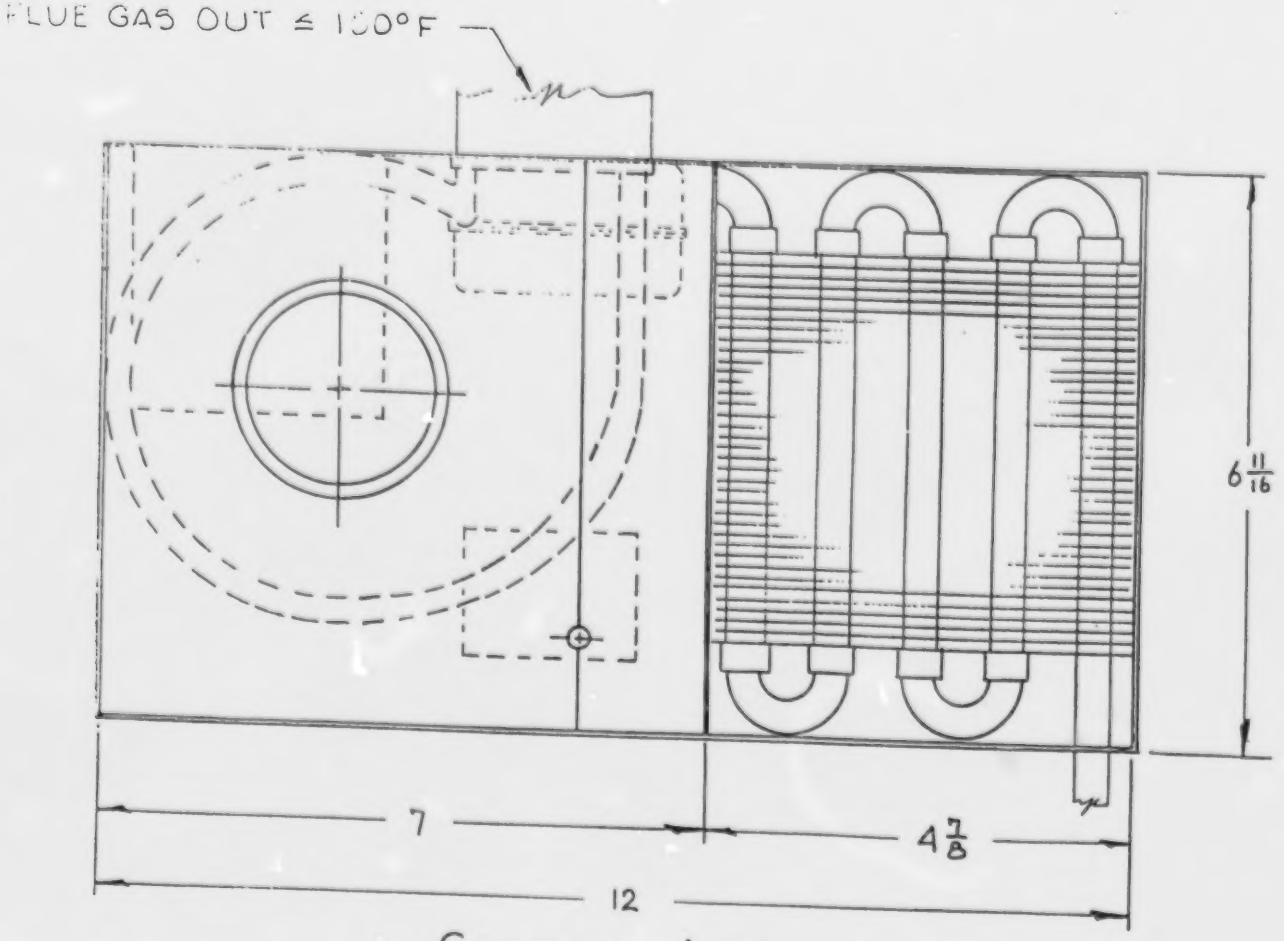
6. The temperatures seen by the primary coil were excessive in certain areas and to reduce these hot spots a coil wrap was attached to the exterior of the combustion chamber. The coil wrap was sufficient to lower the temperatures below the incandescent level of the primary coil but did not effectively raise the temperature of the water through this area to any measurable degree.



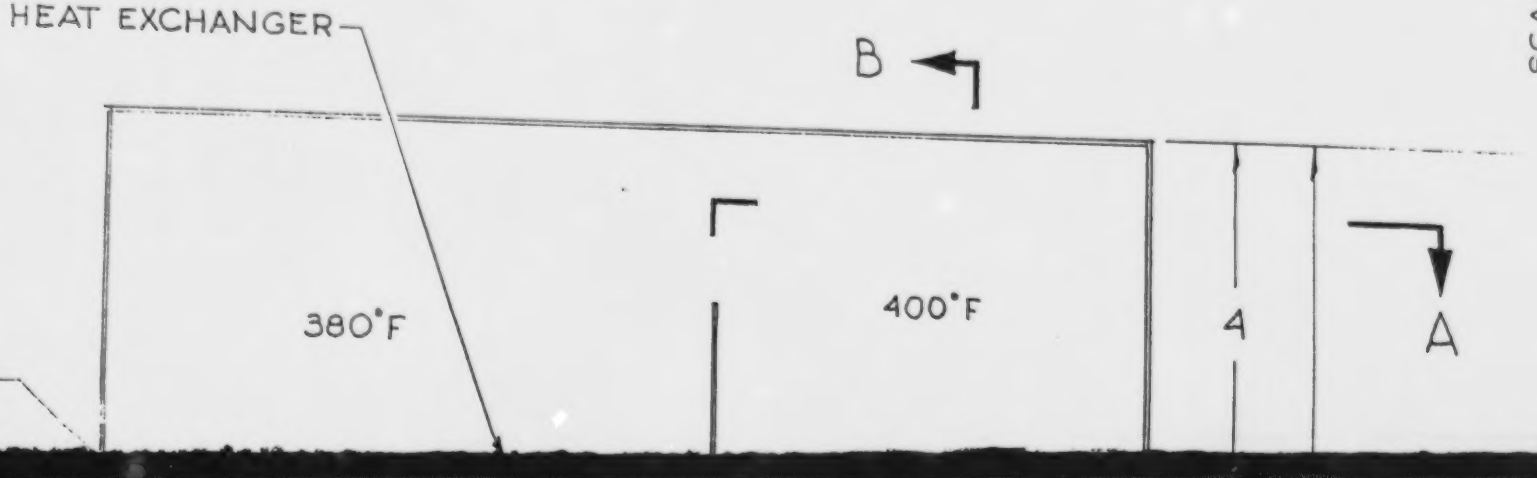
This sketch depicts an early concept of how the water heater was to be approached in design.

The following drawings depict the first design and actual test prototype of the water heater. It was the results from these tests that lead to the final development of the water heater as described within this report.


NDENSATE
IELD
180°F
160°-200°F
WATER
OUT
ONDENSATE
AN
A
6
18 5/8 REF.
BURNER
OWER
COMBUSTION
AIR IN -
310 CFH
10TOR
ANSFORMER
2 STAGE
VALVE
GAS IN
RELAY
B
P/D SWITCH



SECTION A-A

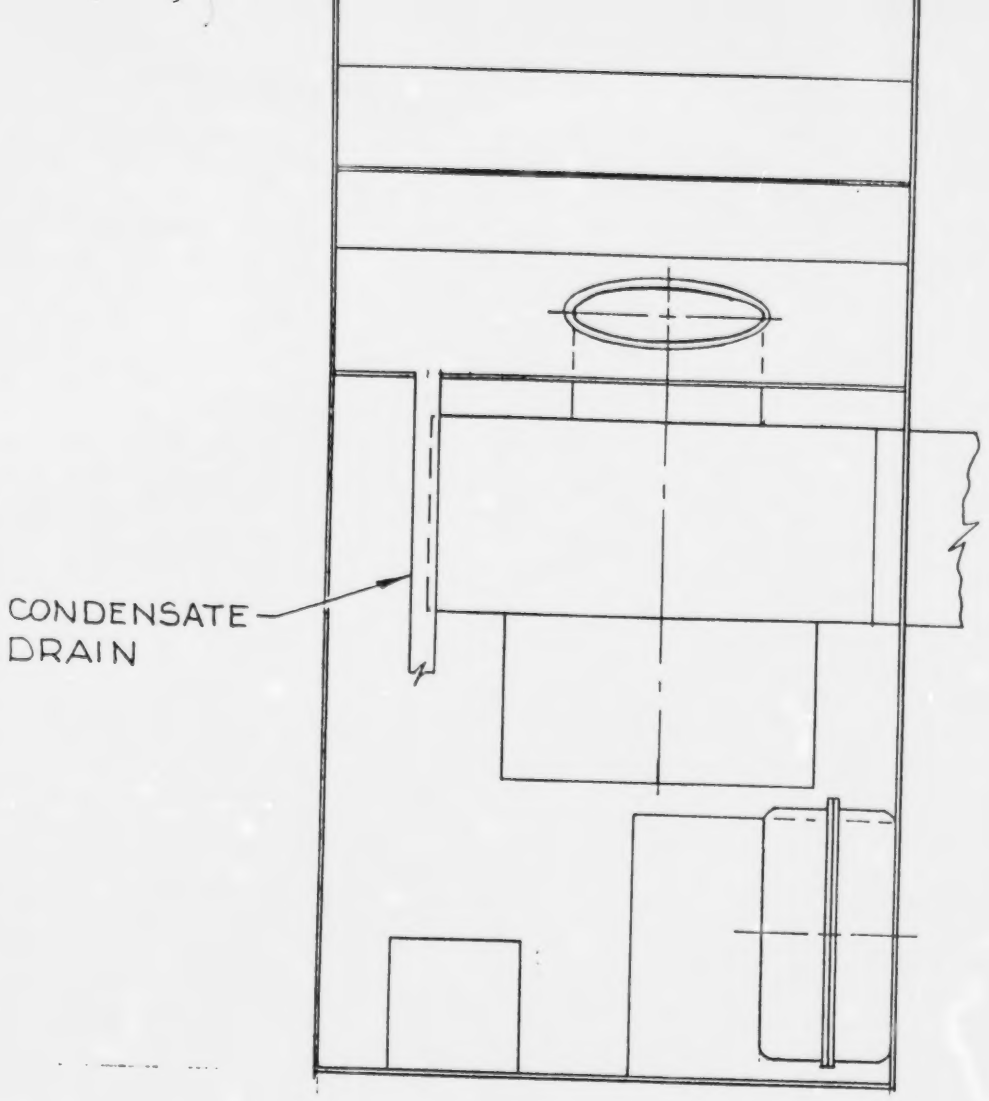


ENERCOIL RESEARCH LTD.
Concord, Ontario - Ontario

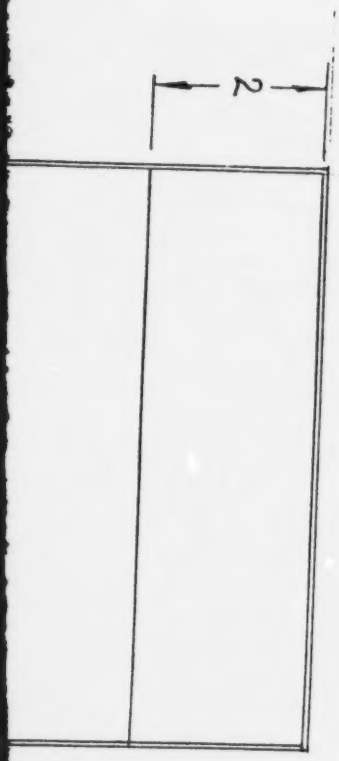
D.H.W. GAS CONVERS. UNIT

DR'N BY: J. ONO	DATE 84-7-12	DRAWING NUMBER 2	REV
CH'D	APP'D		

SCALE 1:2
PAGE 1 OF 2



SECTION B-B



SCALE 1:2

PAGE 2 OF 2

MAT'L - SIZE -	QTY.	USED ON

REVISION	BY	DATE	ECR

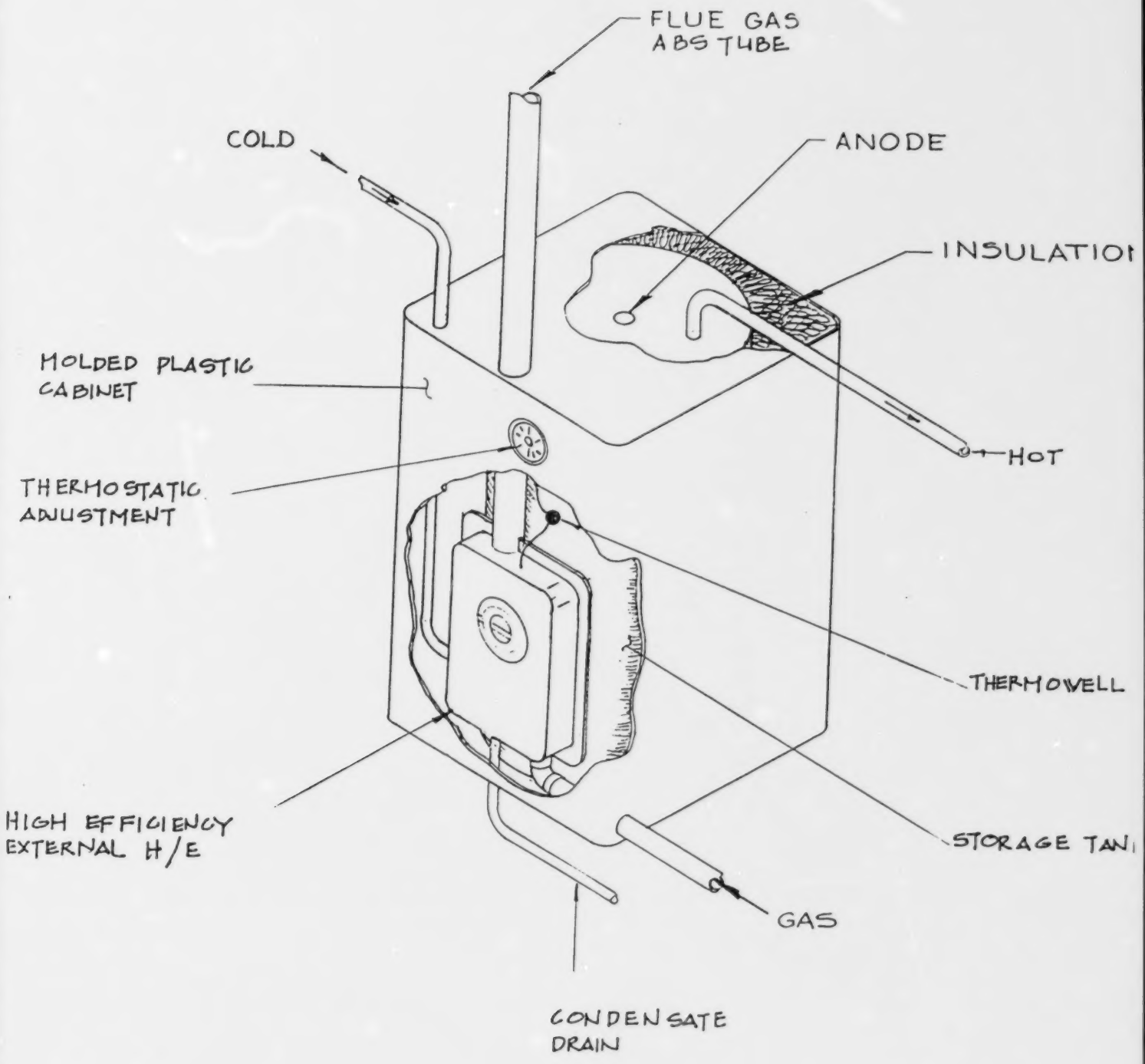
ENEROIL RESEARCH LTD.

Concord, Ontario - Ontario

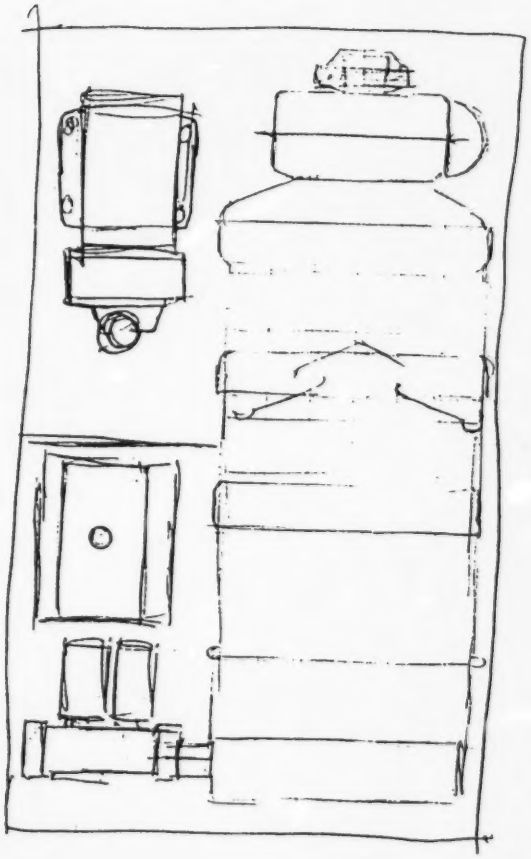
D.H.W. GAS CONVERS. UNIT

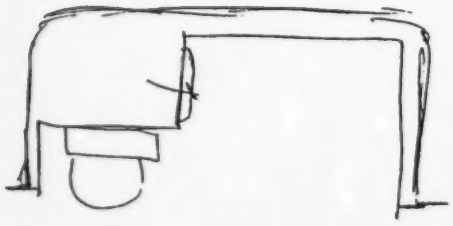
DR'N BY	DATE	DRAWING NUMBER	REV
J. ONO	84·7·12	2	

CH'D BY		APP'D	

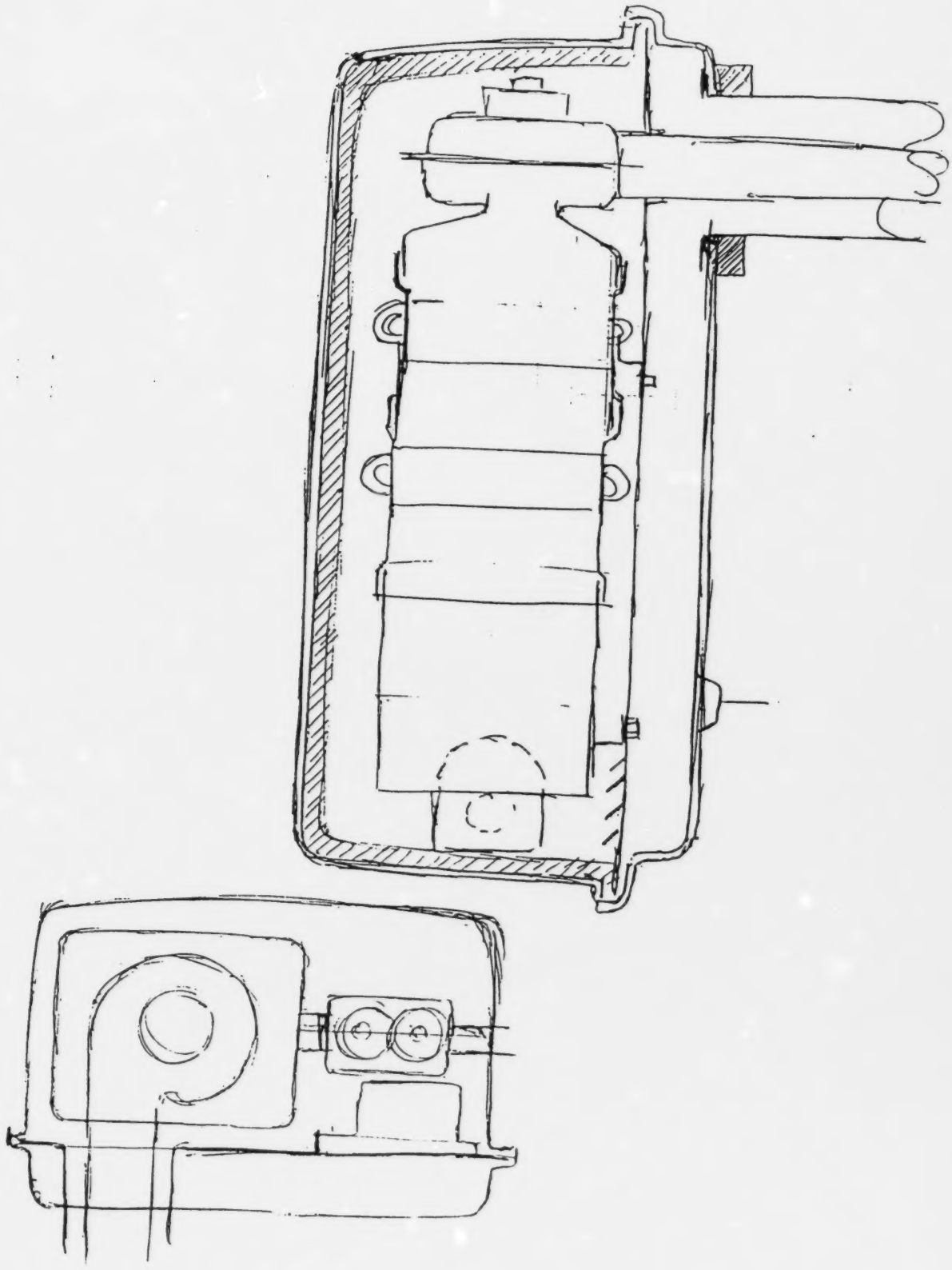


This sketch depicts a concept of integrating the boiler unit and storage tank into a single unit.

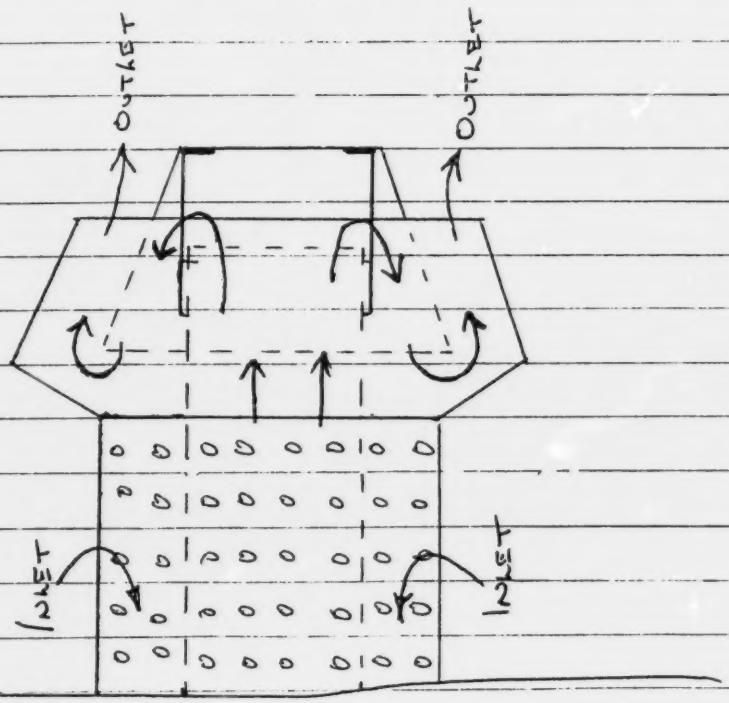




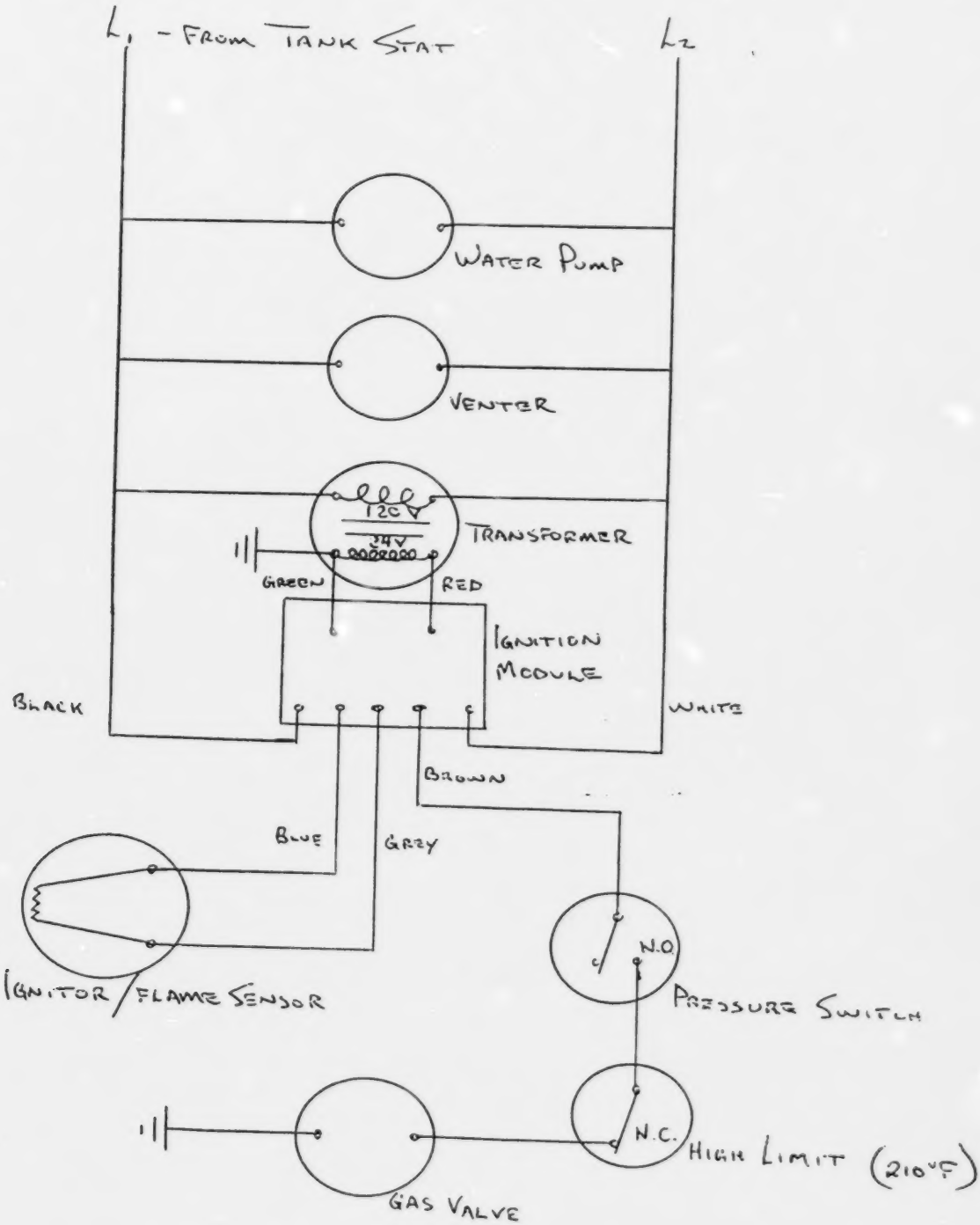
This and the following sketches portray the preliminary arrangement of components as per the final design.



BALANCED FLUE
VENT TERMINAL



WATER HEATER WIRING DIAGRAM



APPENDIX C

Component Sources and Bill of Materials

COMPONENT SOURCES

COMPONENT	SOURCE
Pumps	Armstrong Dunham Busch Grundfos Little Giant Peerless Taco Brydon Brass Underwood Weil Pump March Mfg. *
Heat Exchangers	Larkin Coils Edwards Engineering Universal Heat Exchanger Sundstrand Coils Bohn Heat Transfer *
Venters	Hi Tech Tech Air * Canadian Blowers Dynamic Air Engineering General Blower Co. New York Blower Co. Tjernland Products Westinghouse
Burners	Bray Burners Furigas Inc. * Hirt Combustion Engineers
Valves & Ignition Systems	Honeywell Controls White Rogers Controls Fenwall Inc. *
Pressure Switch	Tri Delta Ranco * Clevelend * Honeywell
Transformers	Honeywell * White Rodgers ITT
High Limit Cut-Off	Thermo Disc *

* Denotes selected manufacturers' products presently being used in the water heater.

HI EFFICIENCY WATER HEATER

BILL OF MATERIALS (A)

NOTE: Does not include Fabricated or Cabinet Parts (Purchased Parts Only)

Part Name	Quantity	Part No.
Circulating Pump	1	3001
Flue Gas Venter	1	3002
Gas Burner	1	3003
Natural Gas Orifice	1	3004
Primary Heat Exchanger	1	3005
Condensing Heat Exchanger	1	3006
Natural Gas Valve	1	3007
Ignition Control Module	1	3008
Silicon Carbide Ignitor	1	3009
Ignition Wiring Harness	1	3010
40 VA Transformer	1	3011
Pressure Differential Switch	1	3012
Thermal Expansion Tank	1	3013
High Thermal Limit Switch	1	3014
Temperature and Pressure Relief Valve	1	3015
3/8" 90° Steel Elbow N.P.T.	1	3016
3/8" Threaded Hose Barb	1	3017
½" Copper Threaded Junctions	3	3018
105°C No. 14 Wire	12 Ft.	3019
3/8" O.D. Plastic Tubing	4 Ft.	3020
½" 90° Copper Elbows	2	3021
½" Copper Tee	1	3022
½" Copper x ½" F.N.P.T.	1	3023
Electrical Spade Connectors	12	3024
1½" ABS Tube	6"	3025

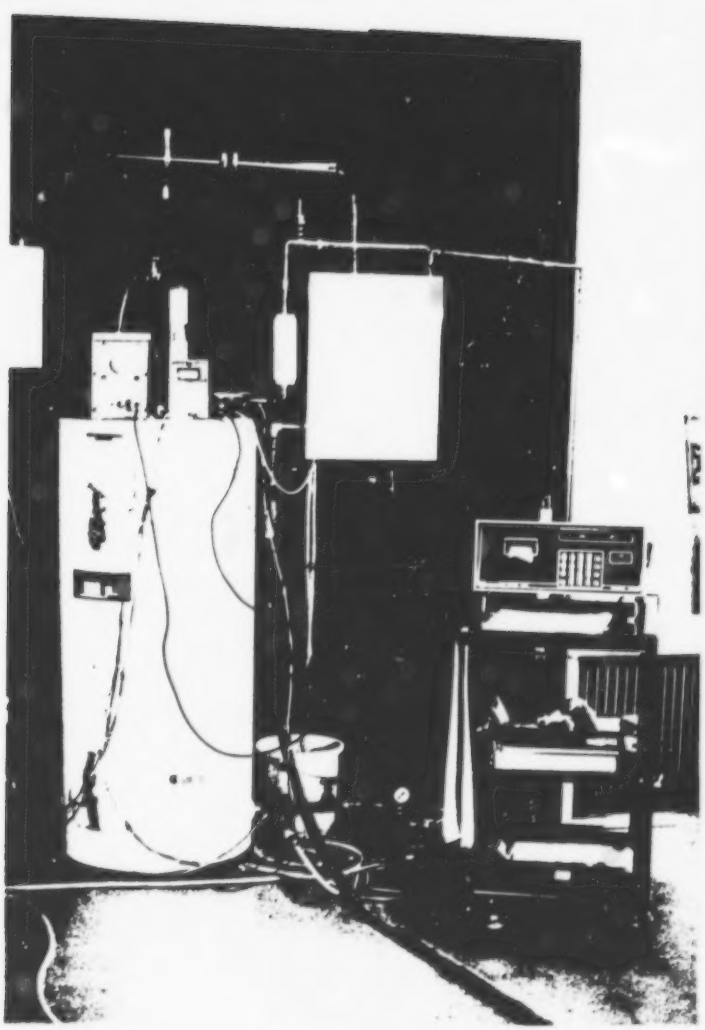
BILL OF MATERIALS (B)

NOTE: Cabinet & Fabricated Parts Only

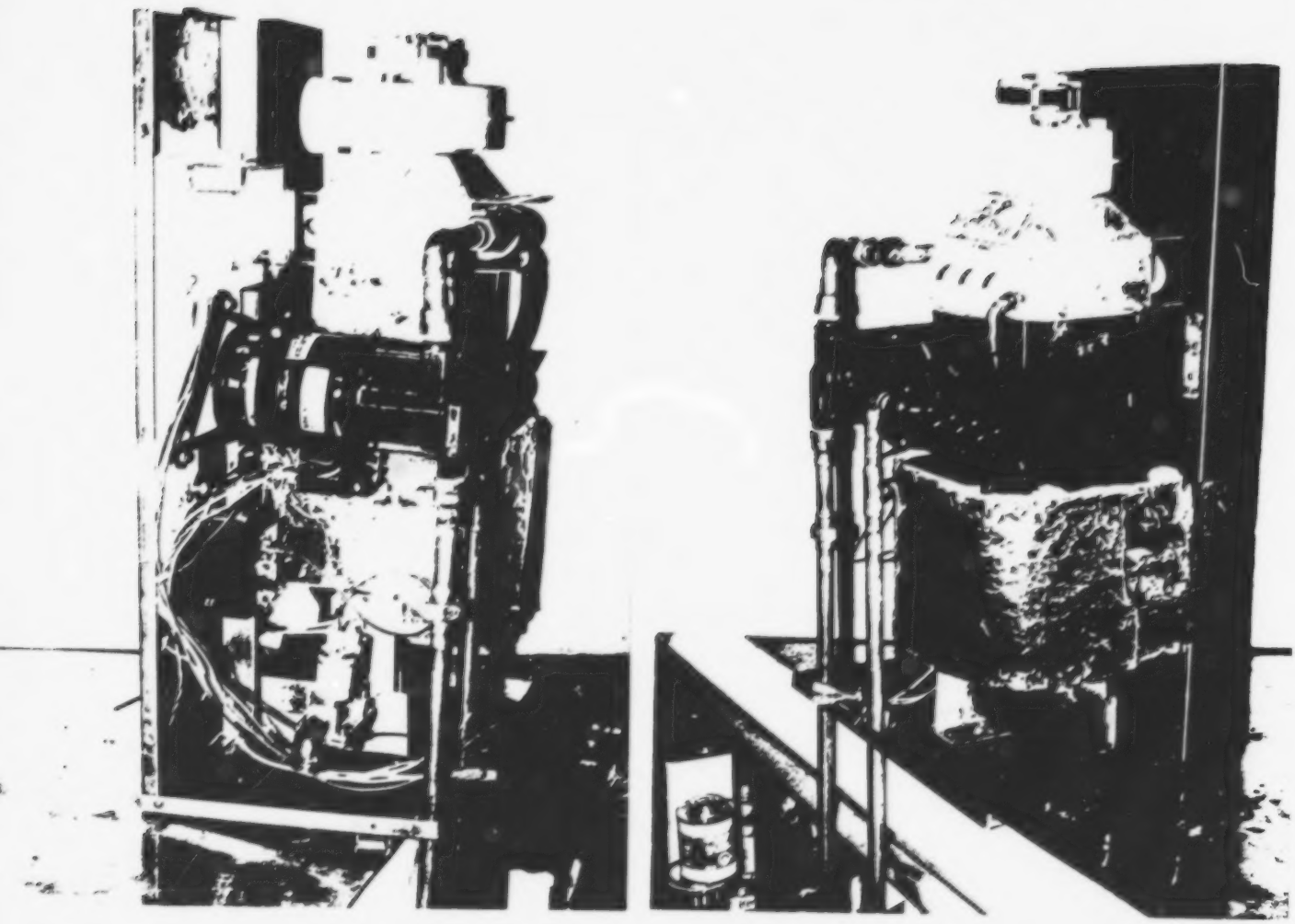
Part Name	Quantity	Part No.	Material	Sq. Ft. Only For Ordering & Costing
Flue Gas & Condensate	1	3100	22 GA Stainless Steel	1.1
Outside Cover	1	3201	22 GA. C.R.S.	6.7
Back Plate	1	3202	22 GA. C.R.S.	2.7
Bottom Plate	1	3203	22 GA. C.R.S.	1.05
Interface Plate	1	3204	22 GA. C.R.S.	2.9
Venter Inlet Adapter	1	3300		
Internal Mounting Plate	1	3400	22 GA. C.R.S.	
Valve Support Bracket	1	3500	22 GA. C.R.S.	
Combustion Chamber	1	3601	28 GA. Copper	
Chamber Coil Wrap	1	3602	½" Cu. Tube	
Chamber Insulation	1	3603	½" Foil Backed	
Bottom Plate Insulation	1	3604	½" Foil Backed	
Pump Motor Belly Band	1	3700	20 GA C.R.S.	

APPENDIX D

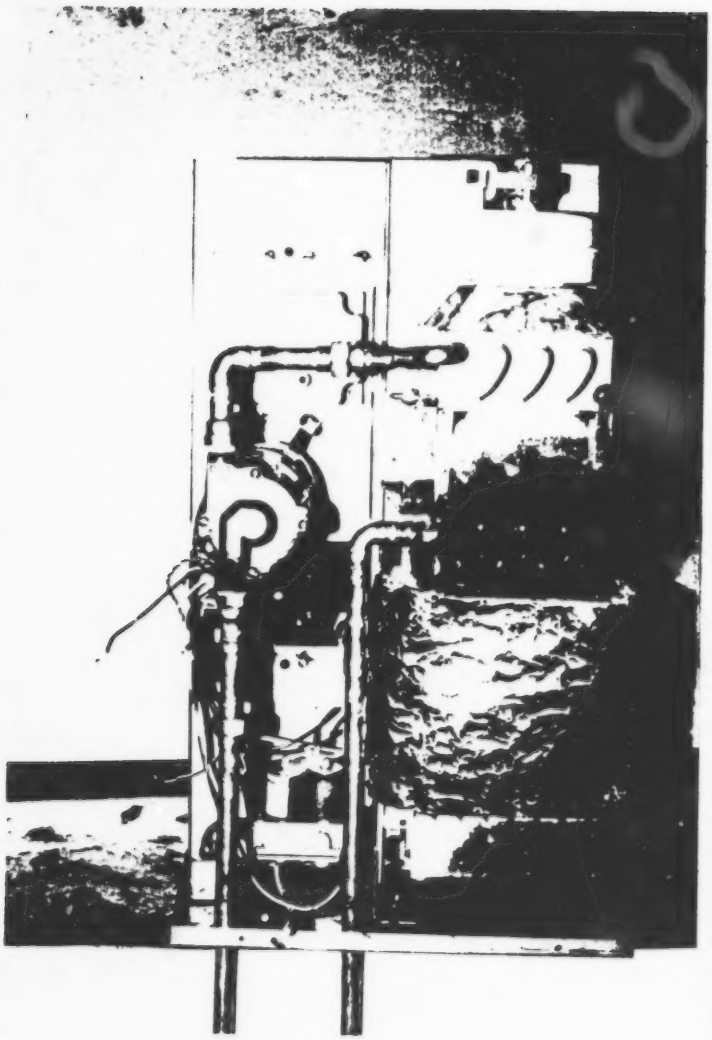
Photographic Record

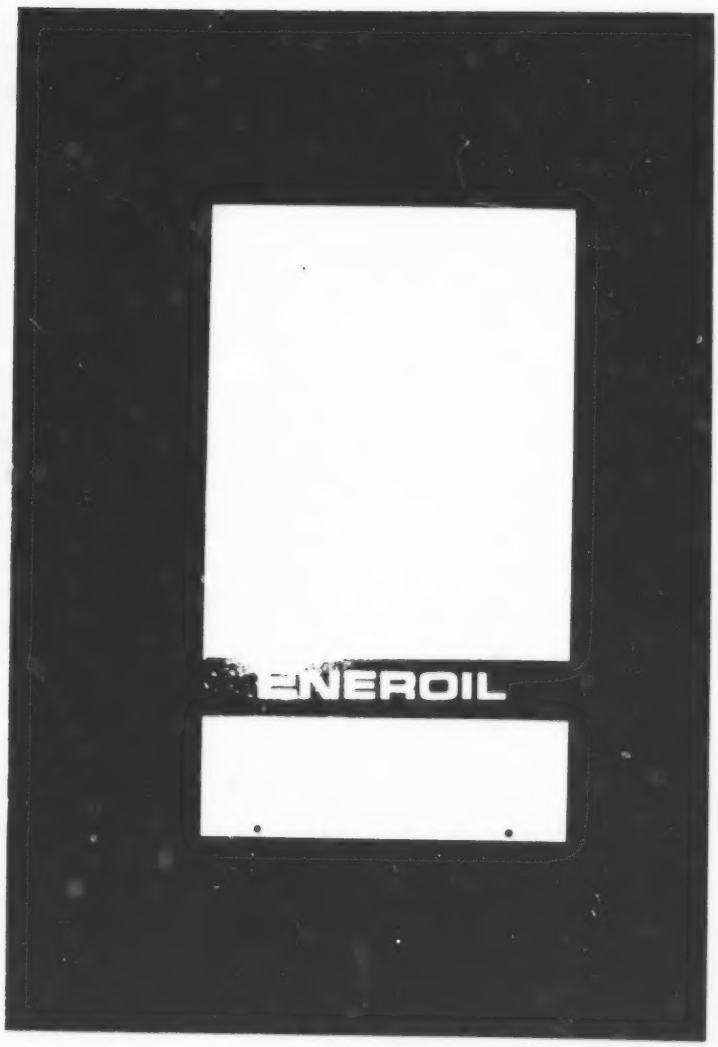


These photos depict the water heater installed in the test area and the assorted test equipment utilized throughout the program.

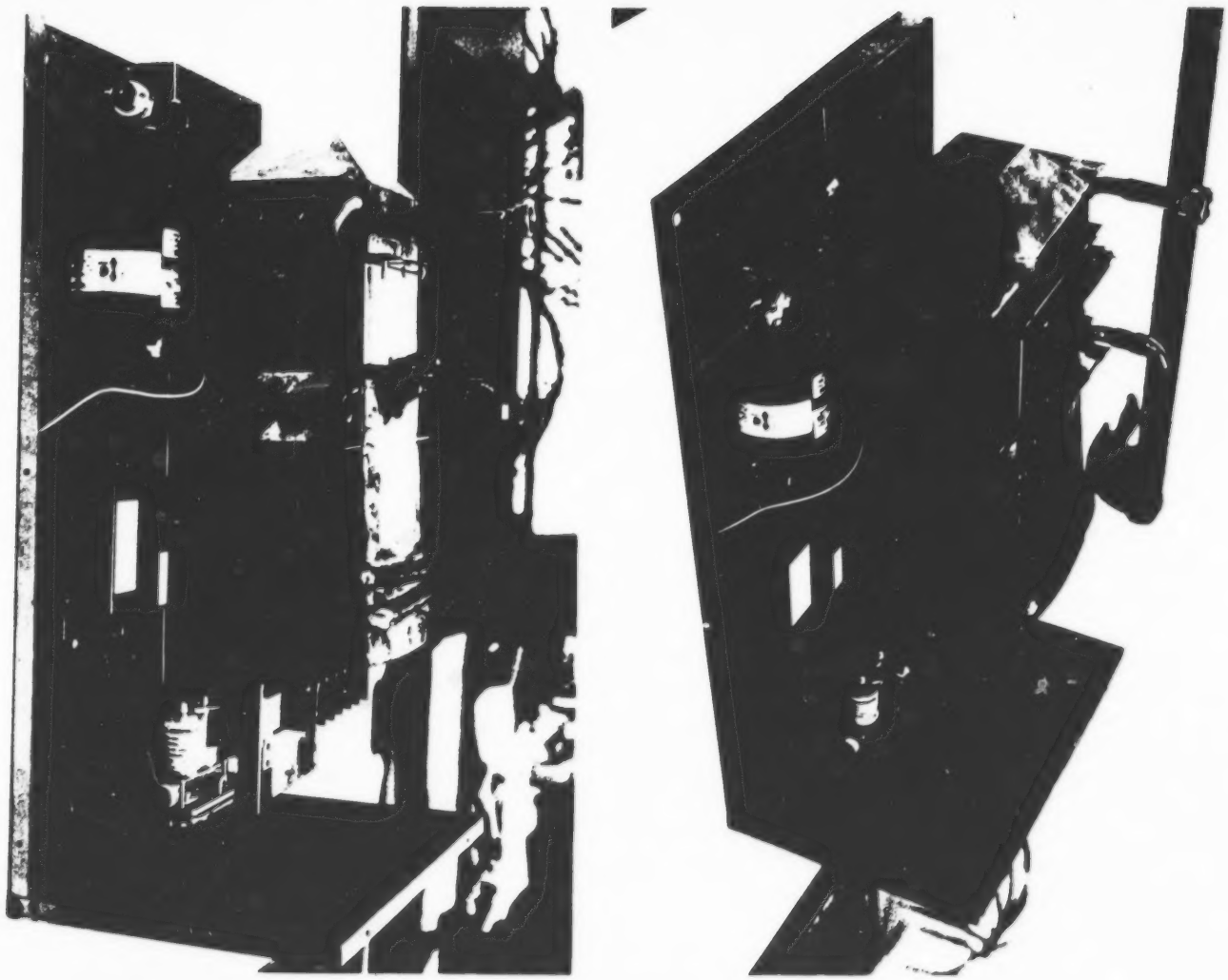


These photos depict the Water Heater in the final assembly stages and reveal the layout of the components within the cabinetry.

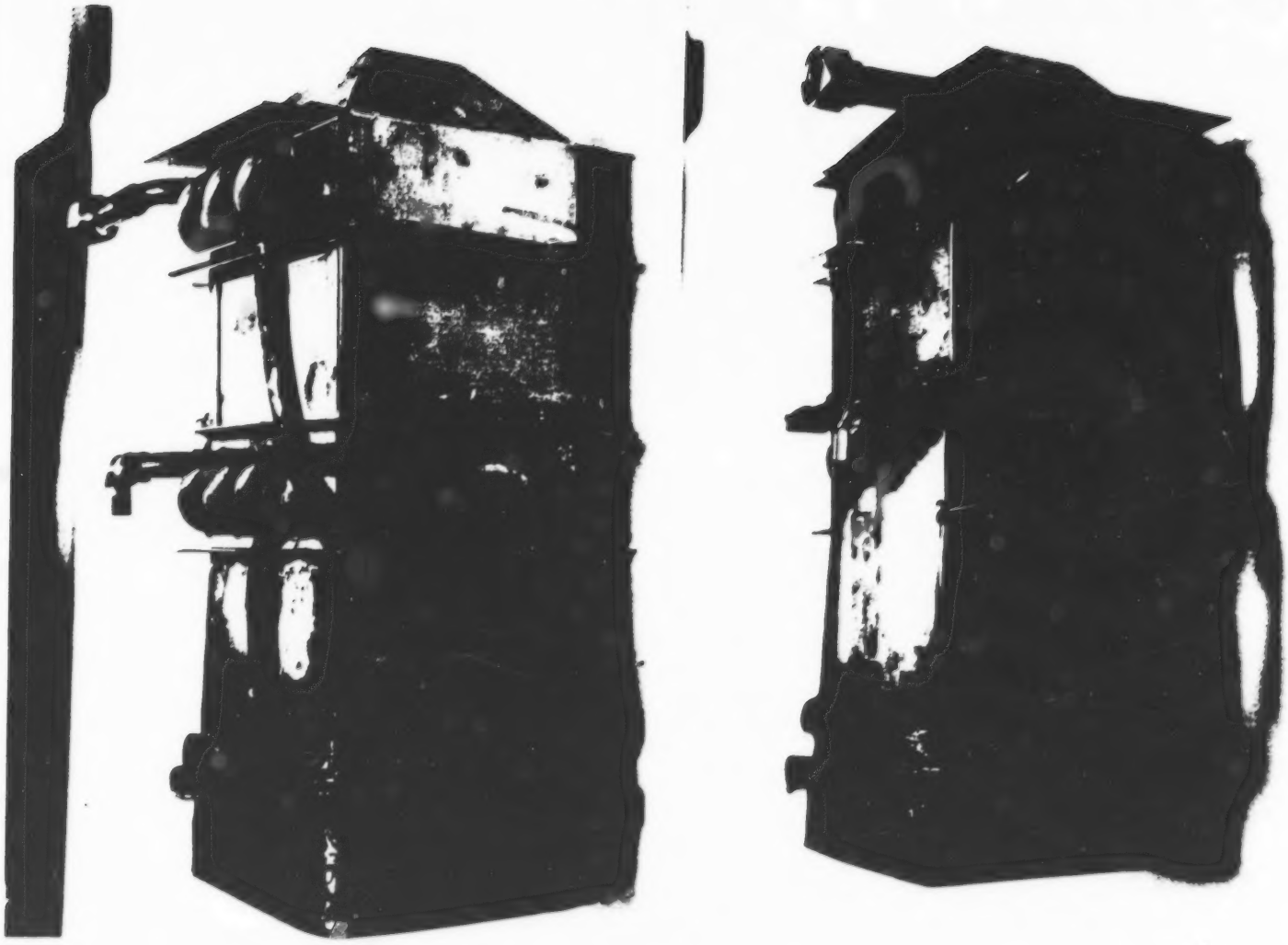




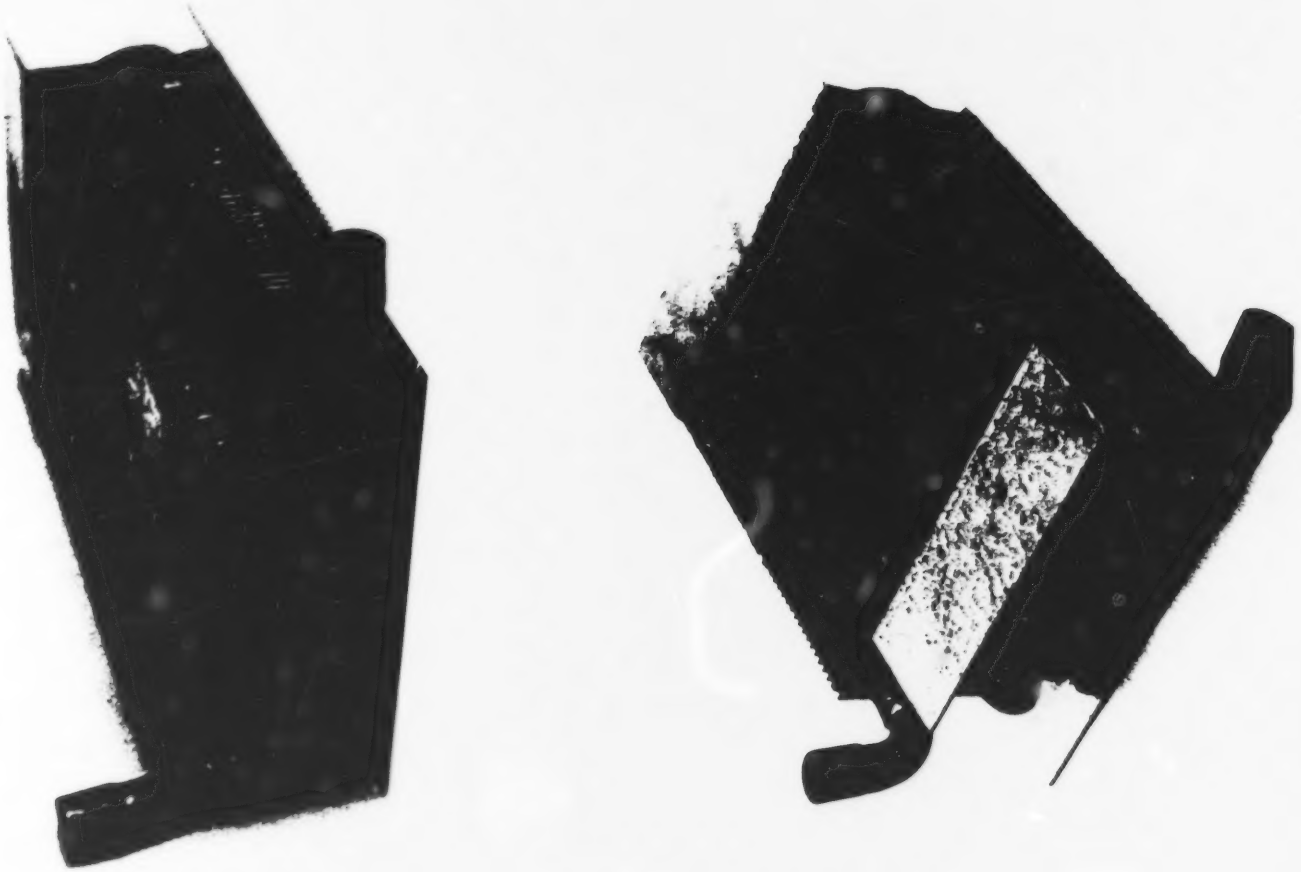
These photos depict the Water Heater in the final stages of assembly including the exterior cabinetry.



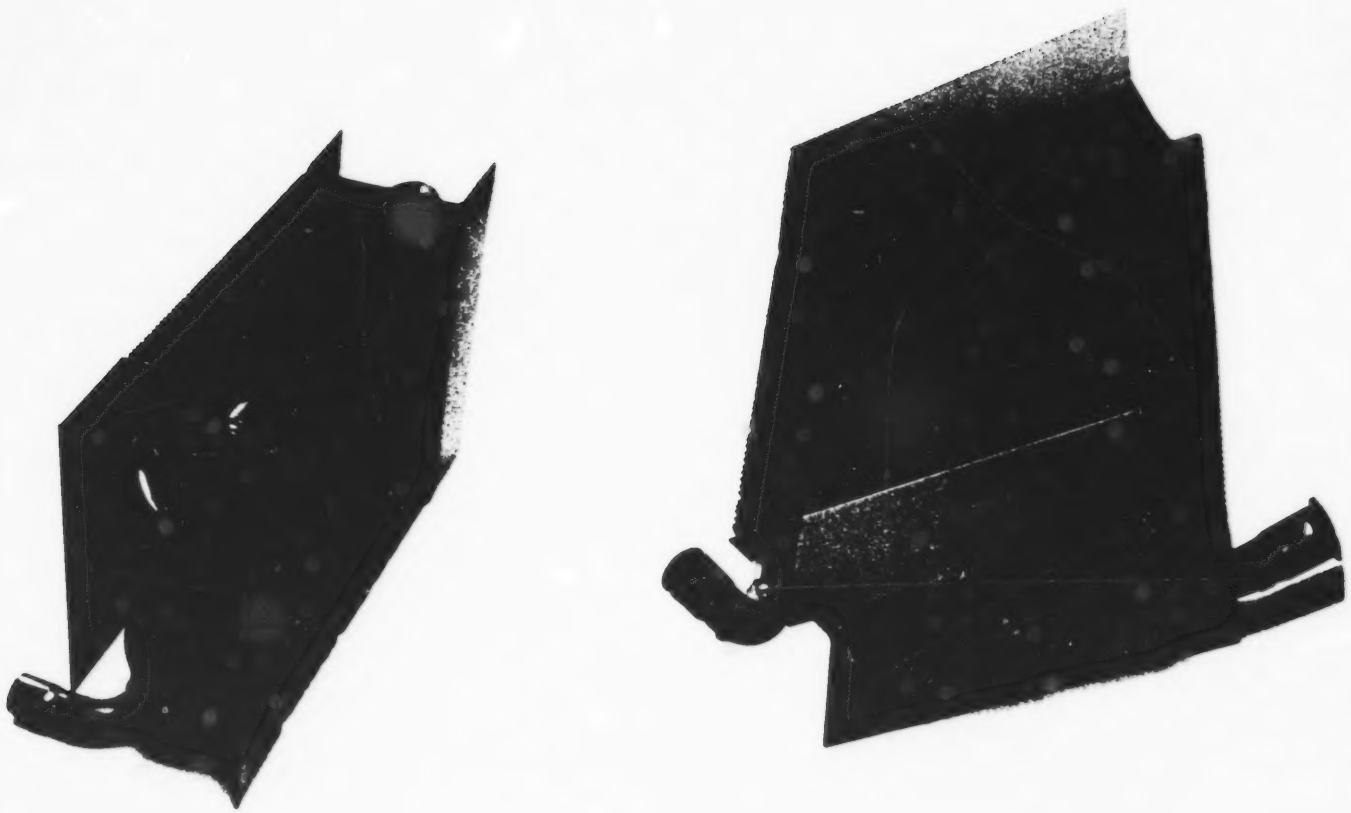
These photos depict the arrangement of the major components within a preliminary cabinet to spatially visualize the organization of the space within the cabinetry.



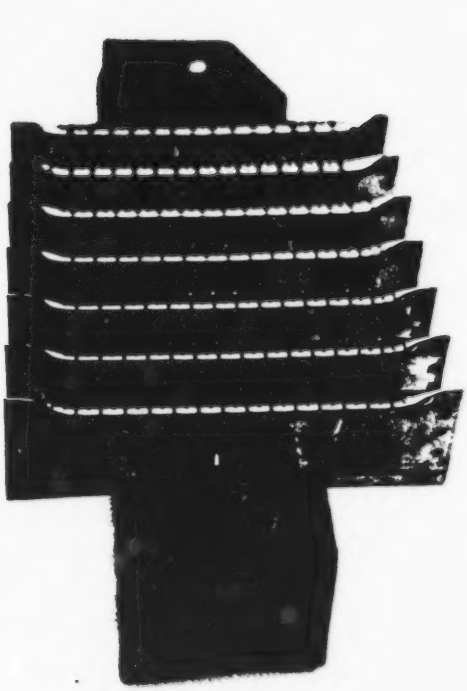
These photos depict the arrangement of the combustion chamber with coil wrap and the primary and condensing heat exchangers stacked on top with the condensate baffle between them and the stainless steel venter adapter on top.



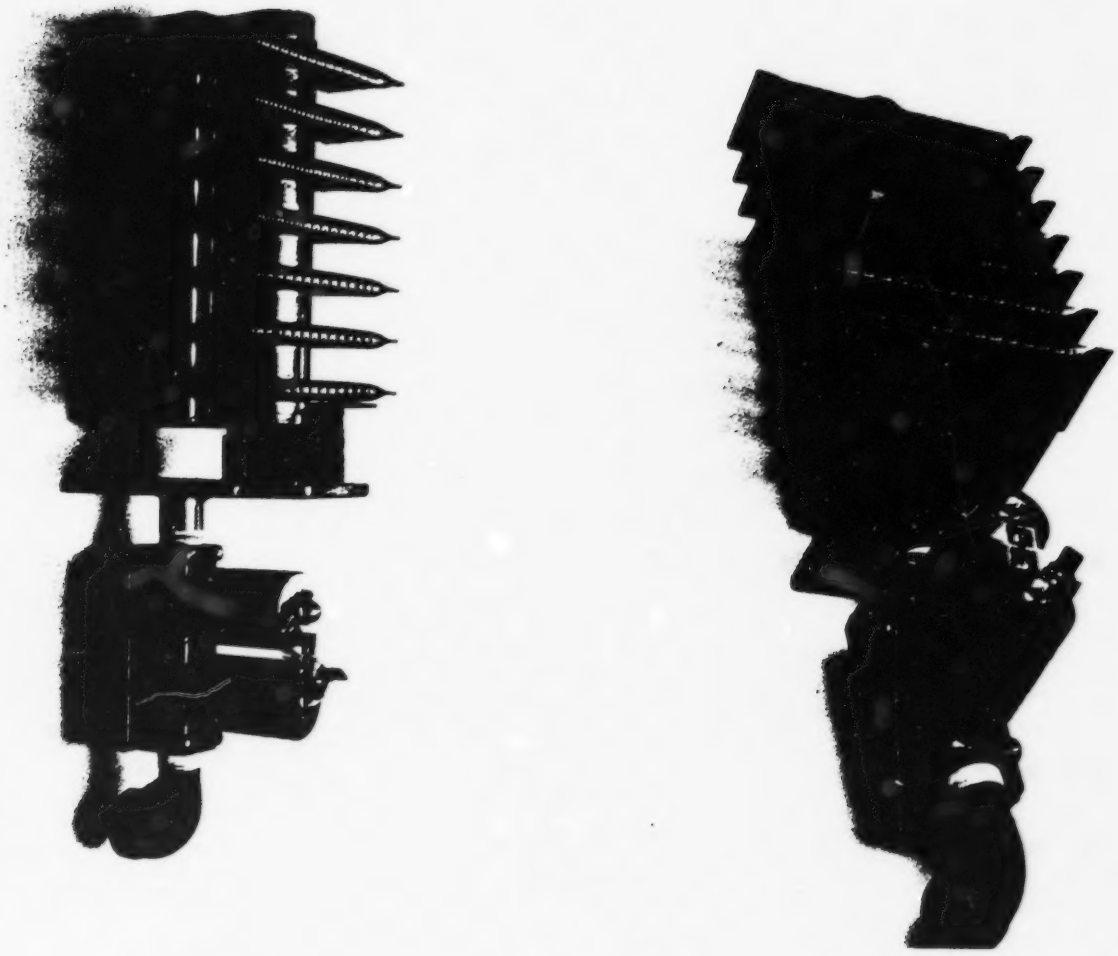
These photos depict the primary copper coil heat exchanger which is manufactured by BOHN HEAT TRANSFER.



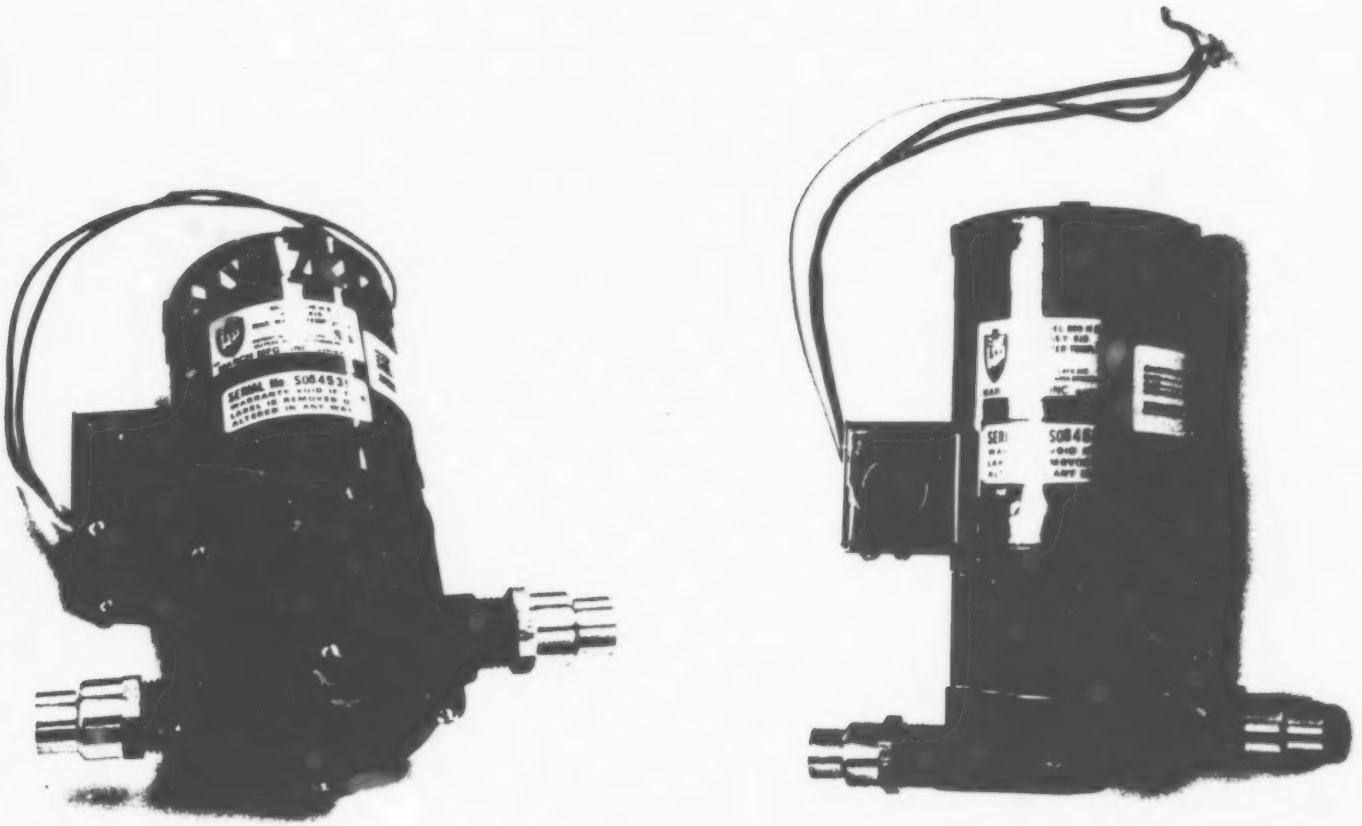
These photos depict the teflon coated condensing heat exchanger coil.



These photos depict the Plan Area Burner manufactured by FURIGAS.

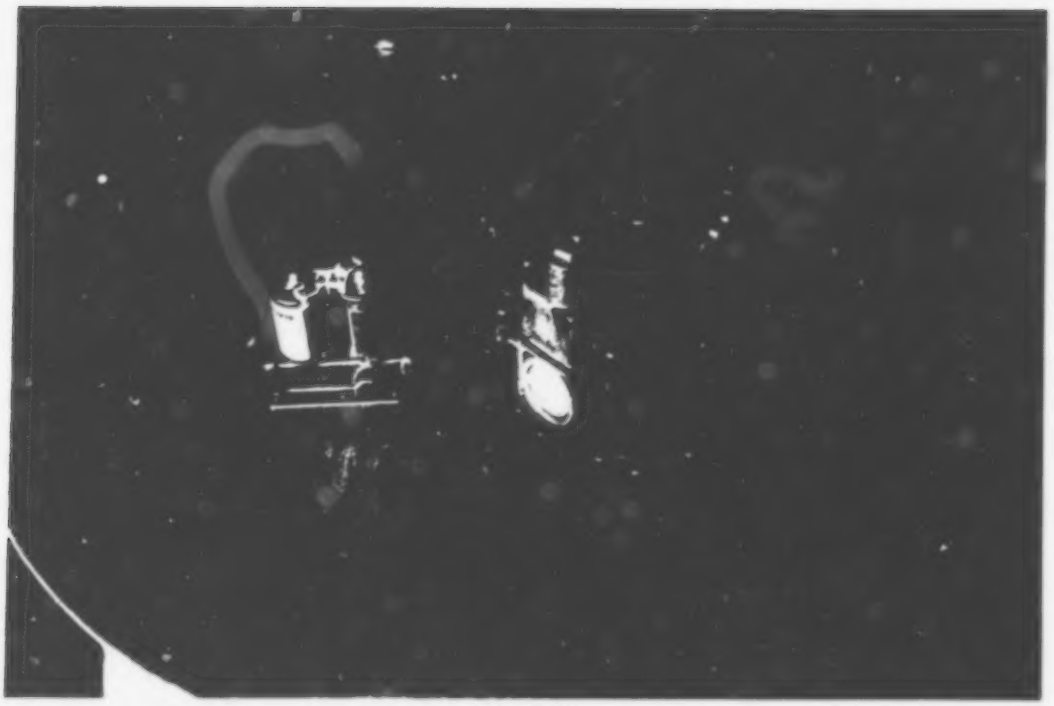


These photos depict the FENWALL gas valve and the FURIGAS burner as a combined unitand readv for installation.

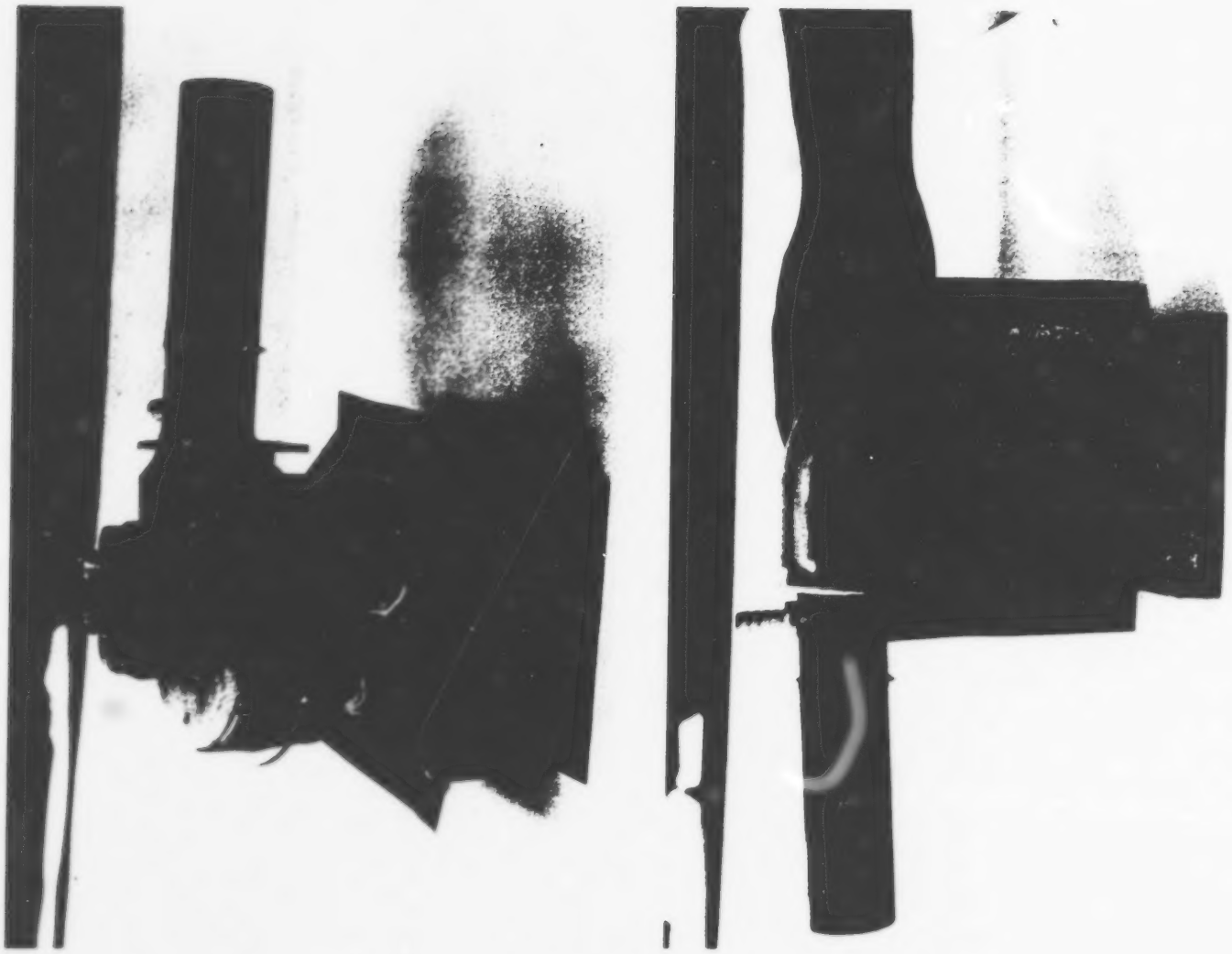


These photos depict the water circulating pump utilized by the water heater.

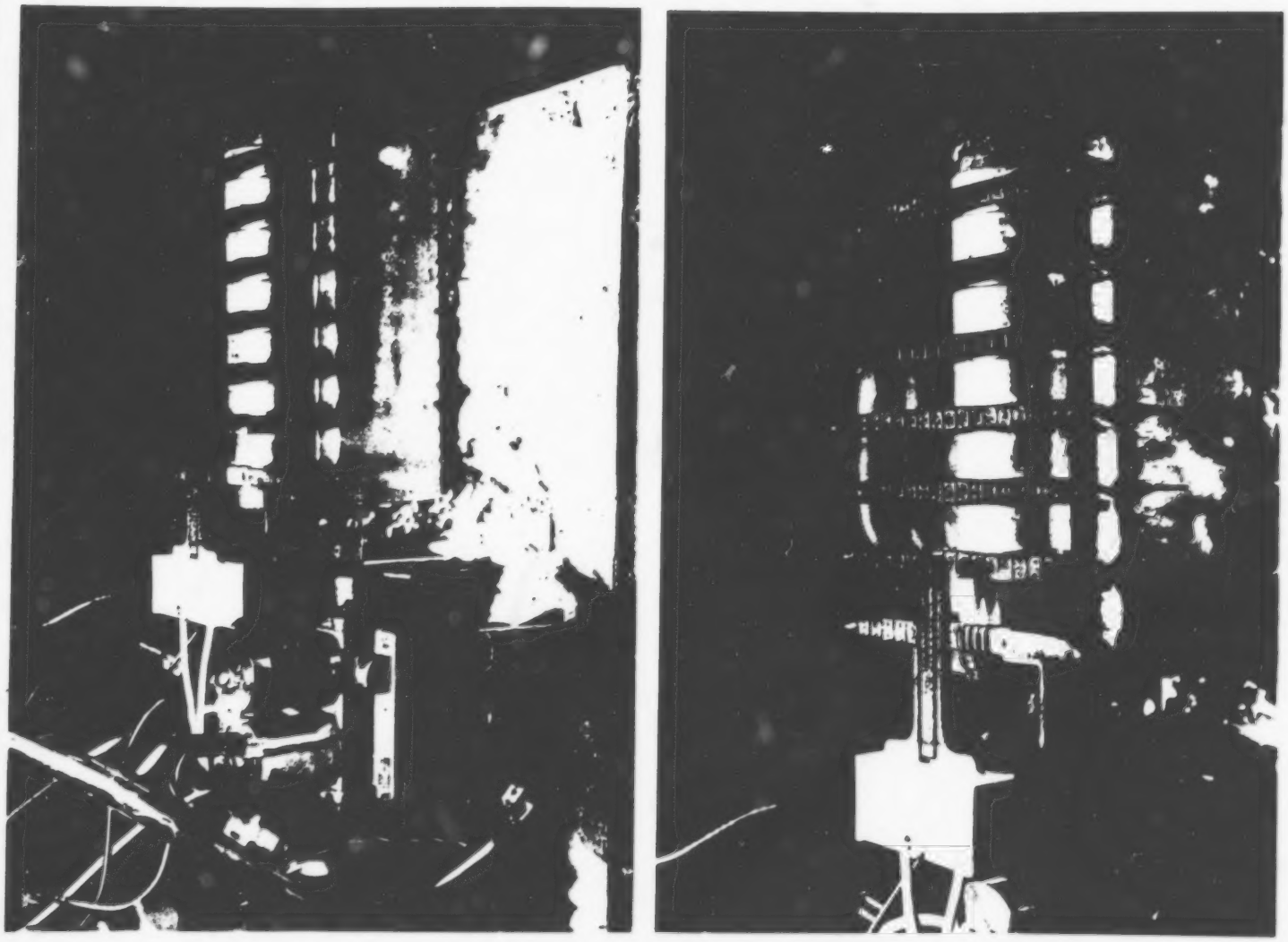
These photos depict the: Ignition Module manufactured by FENWALL; Transformer manufactured by ITT; and Pressure Differential Switch manufactured by CLEVELAND.



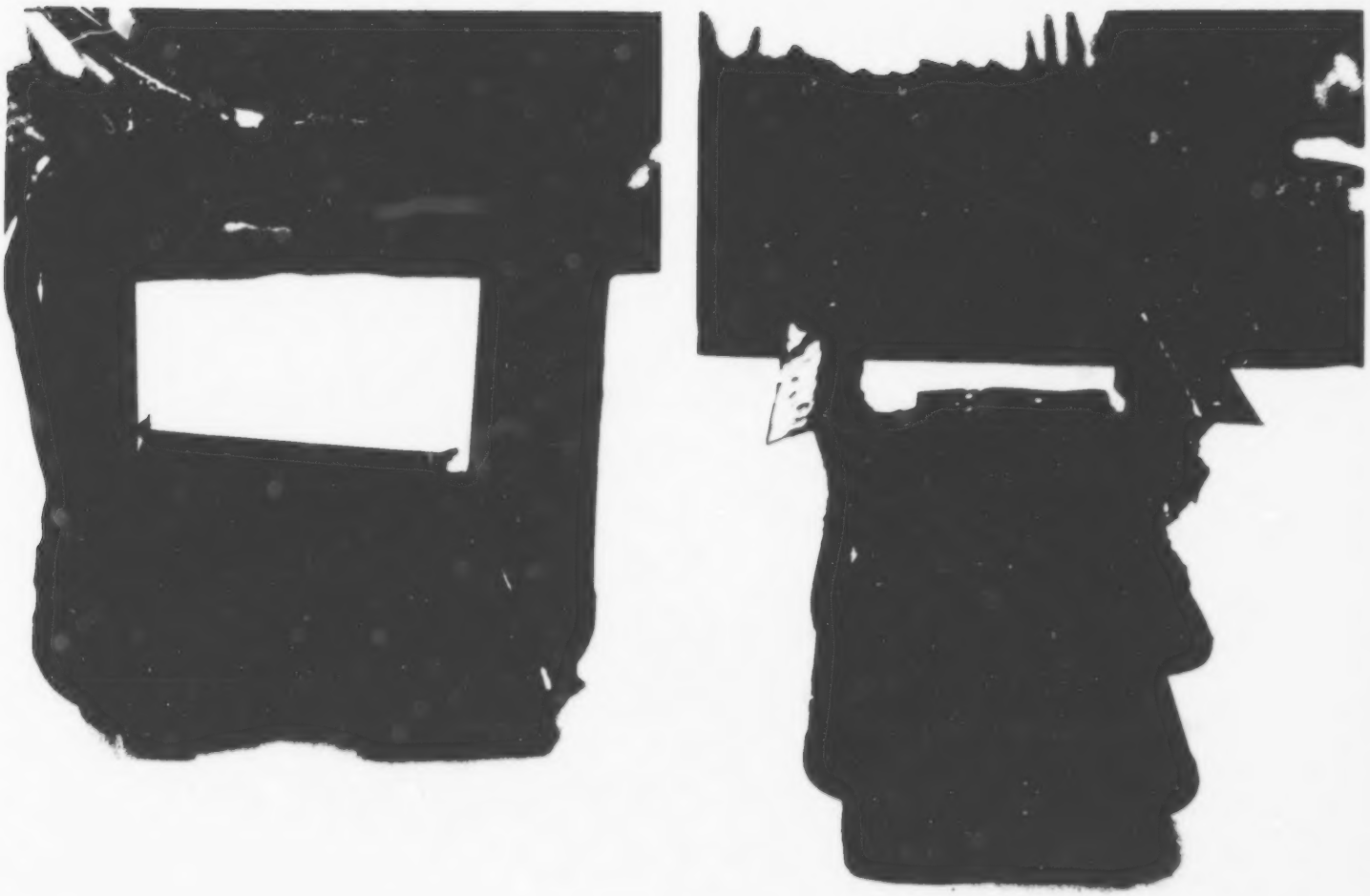
This photo depicts the relatively compact size of the selected FENWALL gas valve as compared to a conventional gas valve.



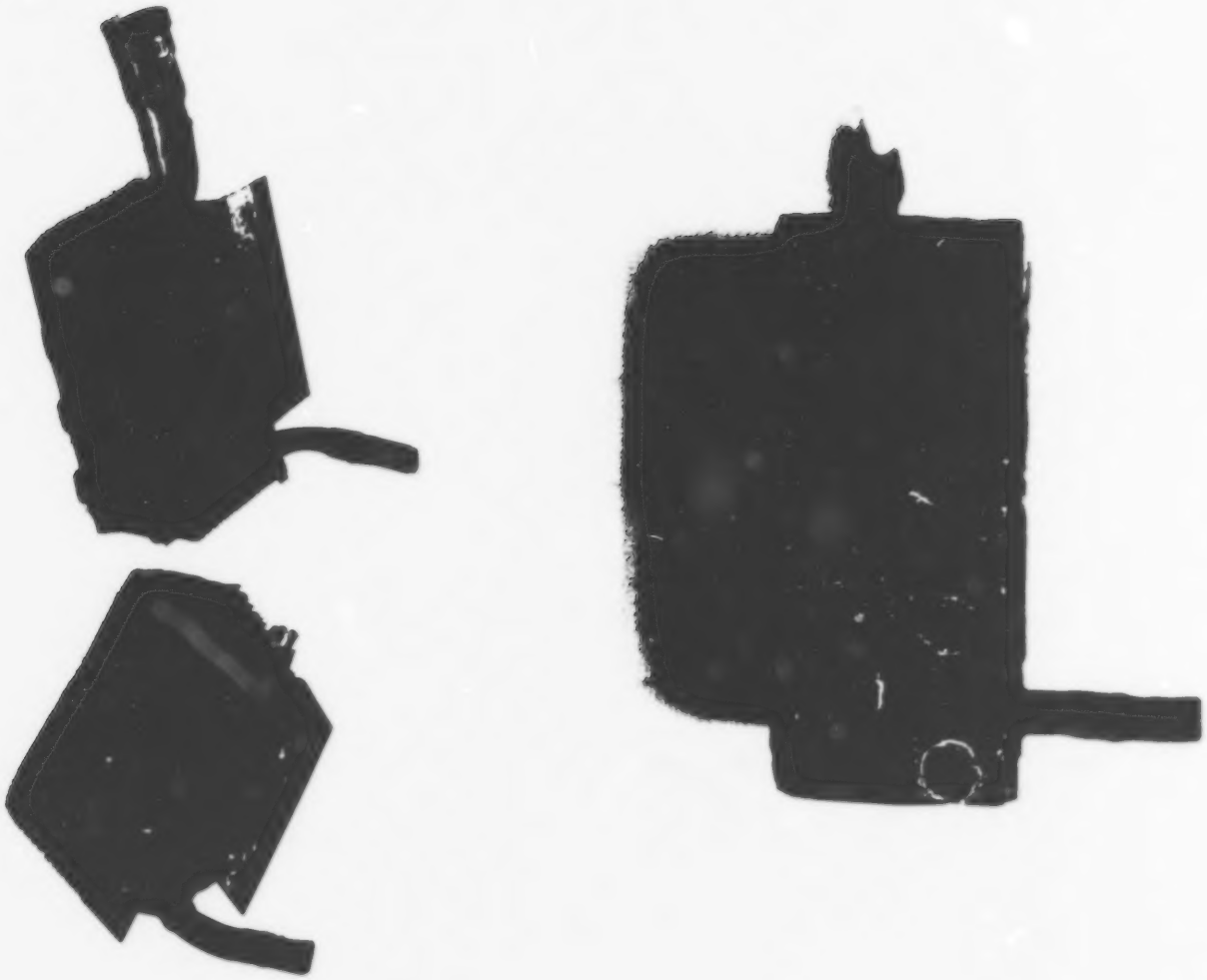
These photos depict the examination of the venter and adapter that were utlized to power vent the flue products of the water heater.



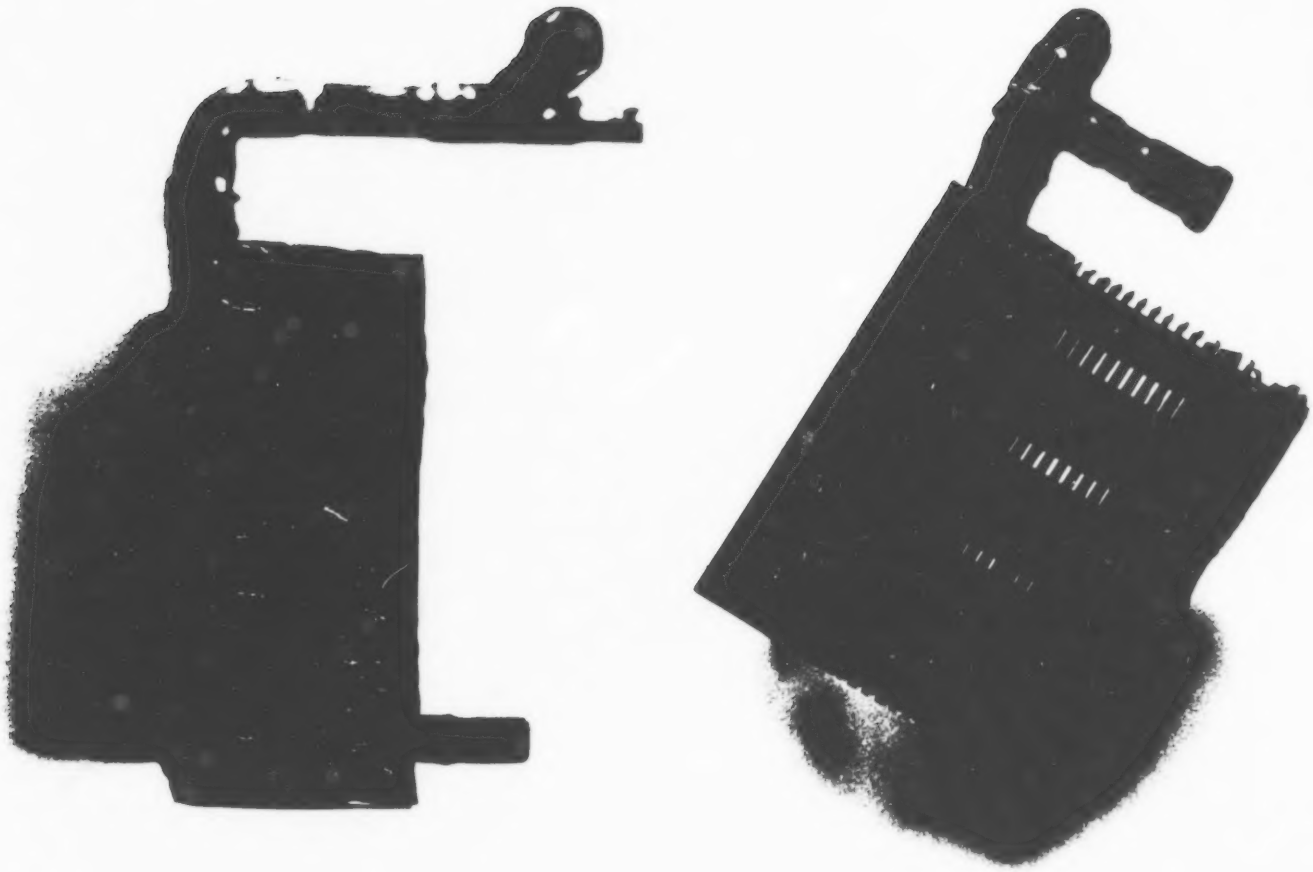
These photos depict the examination of the burner and silicon carbide ignitor as they are installed in the water heater.



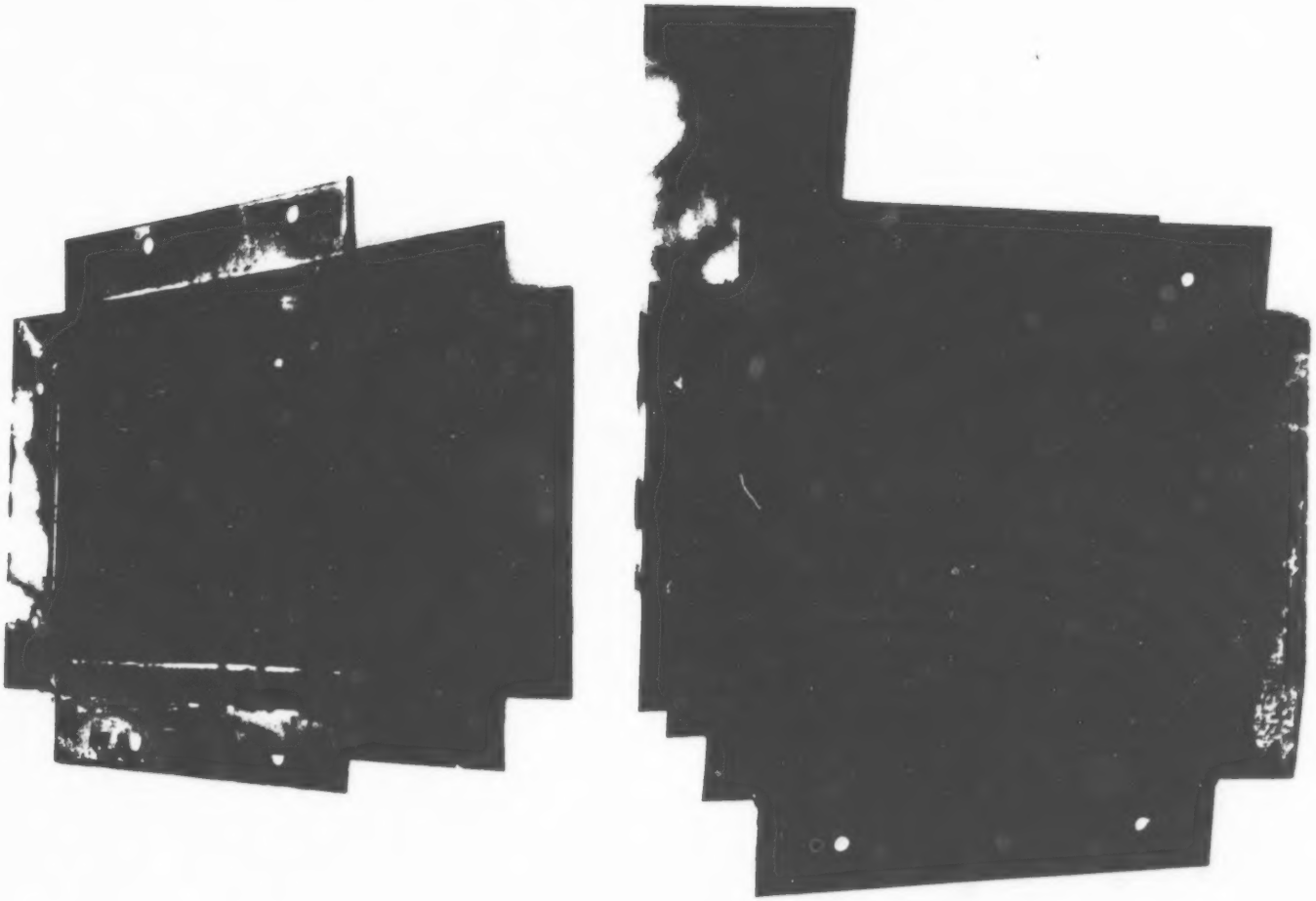
These photos depict the examination of the combustion chamber for signs of degredation following the rigorous test program.



These photos depict the cross-sectioning and examination of the condensing heat exchanger for signs of corrosion.



These photos depict the examination of the primary heat exchanger coil for signs of degredation and corrosion.

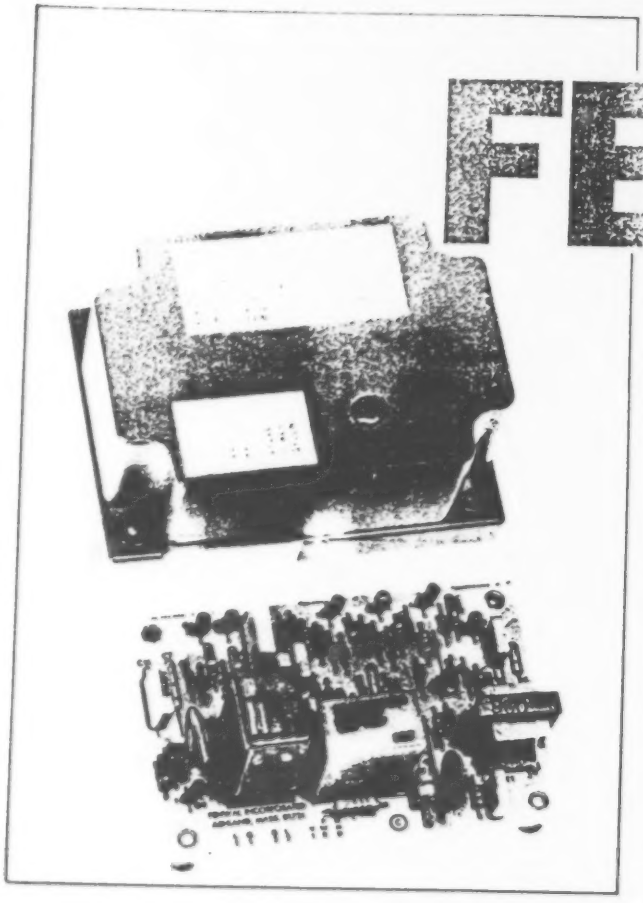


These photos depict the examination of the condensate baffle for signs of corrosion or degredation.

APPENDIX E

Component Manufacturers' Literature

FENWAL®



SERIES 05-21 SILICON CARBIDE IGNITION SYSTEM

INSTALLATION INSTRUCTIONS

Pat. Pending

GENERAL INFORMATION

Utilizing a high energy ignition source and the principals of flame rectification, the 05-21 combines an interrupted means of ignition and monitoring of main burner flame with 100% safety shutoff. Specifically designed for use in residential gas heating applications, the 05-21 can provide positive ignition over a wide range of air/gas mixtures.

PRINCIPLE OF OPERATION

The system utilizes a silicon carbide element that performs a dual function of ignition and flame detection. The ignitor is an electrically heated resistance element which thermally ignites the gas. The flame detector circuit utilizes flame rectification for monitoring the gas flame.

The ignitor serves two functions. Upon a call for heat, the element is powered from the 120VAC line and allowed to heat for 45 seconds (typical). Then the main valve is powered, permitting gas to flow to the burner for the trial-for-ignition period which is typically 7 seconds long, although other timings are available. At the end of this period, the ignitor is switched from its heating function to that of a flame probe which checks for the presence of flame. If flame is present, the system will monitor it and hold the main valve open. If flame is not established within the trial-for-ignition period the system will lock out, closing the main valve and shutting off power to the ignitor. If, during the heating cycle a loss of flame occurs, the system will recycle through the ignition sequence.

MOUNTING

REMOVE 2 CLIPS THAT HOLD CASE TO PC BOARD DURING SHIPMENT.

The Series 05-21 is not position sensitive and can be mounted vertically or horizontally. The case, or printed circuit board, may be mounted with #6 hardware.

Integral standoffs on the bottom of the PC board provide proper electrical and thermal isolation between the board and the mounting surface.

**Design is certified by A.G.A. to ANS Z21.20 Automatic Ignition Systems*

CAUTION: *I Note that both 24VAC and 120VAC are required for the system. Interrupt both supplies before proceeding.*

II Do not apply power to the module until wiring is completed and the system is properly grounded.

CABLE ASSEMBLY

(Fenwal P/N 05-128070-OXX) Last two digits indicate length of wire in inches).

Insert plastic connector onto edge of PC board as shown in Fig. 1. (Connector will not fit if reversed.) Connect leads as follows (See Fig. 4):

CAUTION: 120 Volts

Black wire to hot-side 120VAC line

Gray wire to silicon carbide ignitor
Blue wire to silicon carbide ignitor } Non-polarized

White wire to neutral side of 120VAC line
Brown wire to gas valve (24VAC)

Red wire to 24VAC supply
Green wire to ground (Control module, burner and gas valve must have common ground)

NOTE 3: *If the cable assembly is not ordered from Fenwal, component parts may be procured using Table I below.*

CAUTION: High Voltage

TABLE I

9-pin edge connector	AMP #480519-9 with terminals # 61668 - 1 Molex # 09 - 01 - 1091 with terminals #08-01-0101

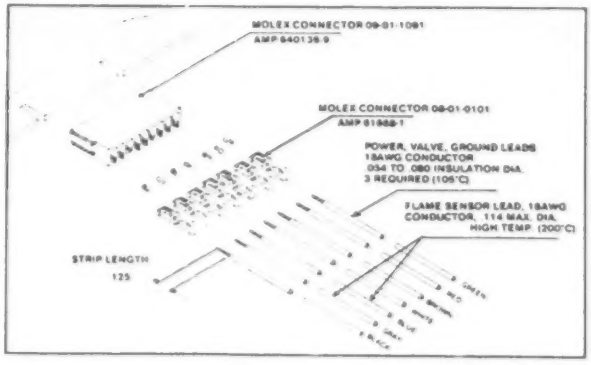


FIG. #1

SILICON CARBIDE IGNITOR

Proper location of the silicon carbide ignitor is important for optimum system performance. It is recommended that the ignitor be mounted temporarily using clamps or other suitable means so that the system can be tested before permanent mounting is accomplished. The ignitor should be located so that it's tip extends ¾" thru the center of the flame and about ½" above the base of the flame.

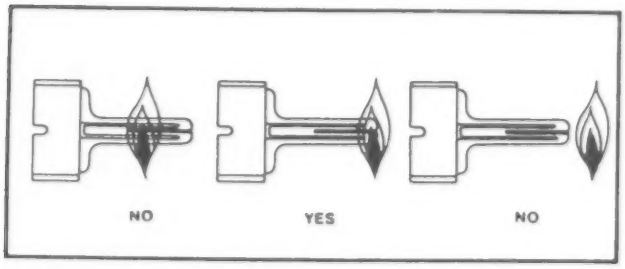


FIG. # 2

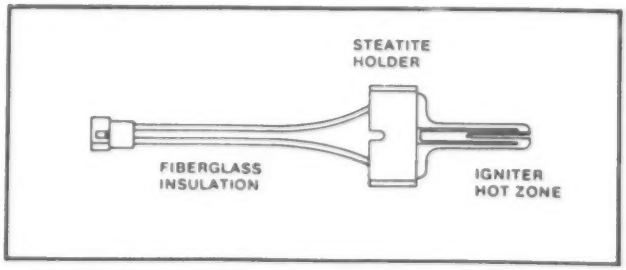


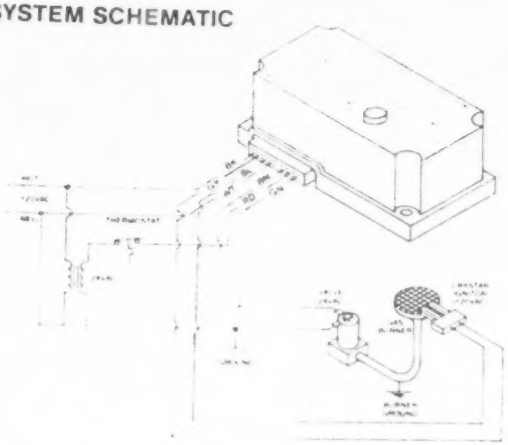
FIG. # 3

PRELIMINARY SYSTEM CHECKS

The system must be checked after installation and before gas supply is turned on.

Be sure that the system is electrically grounded.

FIG. #4A
SYSTEM SCHEMATIC



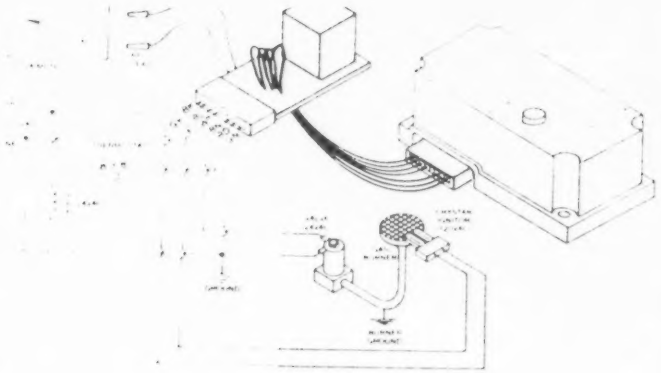


FIG. #4B
SYSTEM SCHEMATIC
WITH TEST ADAPTER IN PLACE

INITIAL OPERATION

1. Check installation, mounting and position of ignitor in the flame envelope.

2. Apply 120VAC power to the system. Manually shut off the gas supply and apply 24VAC power to the system by advancing the thermostat.

3. Check to insure that the ignitor "glows" during the trial-for-ignition period specified for the unit. The system should lock out after the trial-for-ignition period. Set thermostat to the lowest setting.

4. Manually open the gas supply line and advance the thermostat to recycle the system.

5. Check that ignition has been accomplished within the trial period. The ignitor "glow" will diminish after the trial-for ignition period.

6. If the system ignites but fails to hold in check for 5 microamps minimum flame sense current using a Fenwal Test adaptor P/N 05-080223-001 and a 0-50DC microammeter per Figure 4B. Also,insure that the system is properly grounded per Figure 4A.

SAFETY CHECKS

1. Manually shut off gas supply and apply 120V power and 24VAC to the module by advancing the thermostat. After the system has locked out, check that there is no voltage across the gas valve terminals with a suitable voltmeter. Set thermostat to the lowest setting.

2. Wait 15 seconds, then manually open the gas supply and reactivate the system: by advancing the thermostat to a setting above room temperature. The ignitor should glow brightly and then diminish after the flame has been established. While the system is operating, manually shut off gas supply. The ignitor should begin to glow brightly as soon as flame is extinguished. The ignitor should continue to glow brightly for the trial-for-ignition period (system then locks out). Check that there is no voltage across the gas valve terminals.
5. Check that ignition has been accomplished within the trial period. The ignitor "glow" will diminish after the trial-for ignition period.

SERVICE CHECKS

Flame current is the current which passes through the flame from the ignitor/sensor to ground to complete the primary safety circuit. The minimum flame current required for proper operation is five (5) microamps DC. To measure flame current, first DISCONNECT BOTH POWER SOURCES (120VAC & 24VAC). Then connect the Fenwal Test adaptor P/N 05-080223-001 as shown in Fig. 4. Meter reading should be 5 microamps or higher after reconnecting power and establishing flame.

If meter reads below "O" on scale, the meter leads are reversed. Disconnect power and reconnect leads for proper polarity.

If the flame current reading is less than 5 microamps DC, reposition the ignitor in the flame (see Fig. 2) to get a higher reading.

REPAIRS

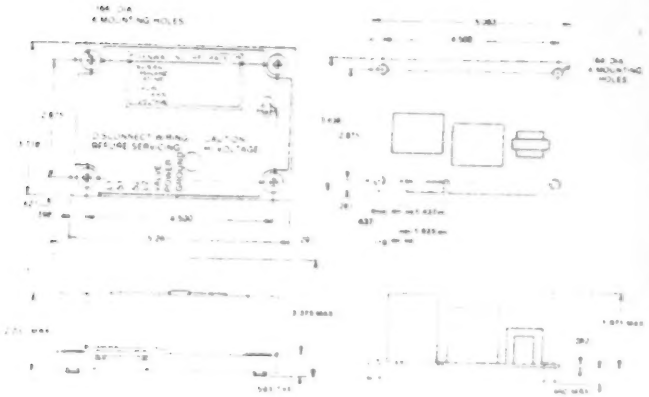
The Fenwal Series 05-21 Silicon Carbide Ignition Module is NOT FIELD REPAIRABLE. Any modifications or repairs to Series 05-21's will invalidate Fenwal's standard warranty as well as agency certifications AND MAY CREATE FIRE, EXPLOSION AND TOXIC HAZARDS TO PROPERTY AND PEOPLE. Faulty units should be returned to the factory for repair or replacement.

SPECIFICATIONS

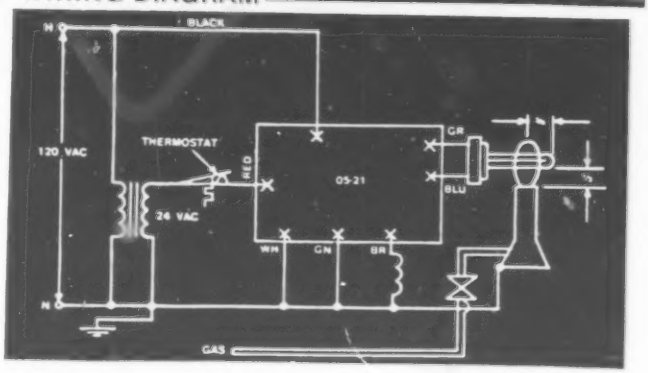
CONTROL MODULE	COMMENTS
[illegible]	[illegible]
[illegible]	[illegible]
TRIAL FOR IGNITION PERIOD (Nominal):	0.8 Seconds
IGNITION MEANS:	[illegible]
FLAME FAILURE RESPONSE TIME:	Less than 8 seconds
INPUT VOLTAGE:	[illegible]
INPUT CURRENT DRAIN:	100 mA, Max. (control only)
AMBIENT RANGE:	-40 to 150° F
IGNITER RELAY CONTACT RATING:	5A Max. @ 120VAC
TYPE OF GAS:	[illegible] Manufactured
MOISTURE RESISTANCE:	to 90% Relative Humidity
VALVE RATING (RELAY CONTACT):	[illegible] Continuous @ 24VAC

Specifications subject to change without notice.

OUTLINE DIMENSIONS



WIRING DIAGRAM



CAUTION: *The Fenwal Series 05-21 Silicon Carbide Ignition Systems are designed for use only on new products by manufacturers of gas fired equipment. It may be used as such, or as replacement for an existing Fenwal Ignition System. Any substitution or application must be expressly approved by Fenwal or the manufacturer of the equipment. Improper substitution or application may result in malfunction of equipment such as loss of flame sensing safety circuit creating an explosive atmosphere.*

LIMITED WARRANTY STATEMENT

[illegible] Incorporated represents that this product is free from defects in material, [illegible] only product or part thereof which proves to be defective in workmanship or material for a period of 18 months after delivery of the product to the buyer. For a full description of Fenwal's LIMITED WARRANTY, which, among other things, limits the duration of warranties of MERCHANTABILITY and FITNESS FOR A PARTICULAR PURPOSE, [illegible] DAMAGES, please read the entire LIMITED WARRANTY in the Fenwal Quotation, Acceptance of Order and or Original Invoice which will become a part of your sales agreement. Defective units should be returned to the factory, Ashland, Massachusetts, shipment prepaid. Fenwal Incorporated will repair or replace and ship prepaid.

FENWAL INCORPORATED

Division of Walter Kidde & Company, Inc.

KIDDE

Ashland, Massachusetts 01721

05-21C 5M 5-83 Printed in U.S.A.

5000 SERIES
AIR SENSING SWITCHES

Low pressure sensitivity and an extremely wide adjusting range characterize 5000 series switches. These controls accurately and consistently respond to pressures as low as .03" W.C. In the case of field-adjustable models, a unique *variable force* spring concept provides a full range of set point adjustments to a maximum of 12.0" W.C.

By design, the *variable force* spring concept assures excellent set point repeatability with narrow switching differentials at the lower end of its range. Automatically, at higher set points, the force characteristics are transferred providing progressively wider switching differentials to assure uninterrupted operation under high shock and vibration conditions.

Further, all critical operating components in 5000 series switches were field tested and specifically selected to withstand and provide stable and reliable operation under extreme temperature and humidity conditions. The entire series is further complemented by a host of options listed below and we invite your inquiry for other products and options available.

"FP" FIXED SET POINT

"FP" style switches are widely used where basic on/off switching is required. The non-adjustable fixed set point feature provides excellent tamper-proof protection. Several standard fixed set points are available ranging from an ultra-sensitive .03" W.C. operating point up to approximately .50" W.C.

"FS" CALIBRATED FIXED SET POINT

"FS" style switches pick up where "FP" style switches leave off. While maintaining tamper-proof protection, this line also features ultra-sensitivity, a greater selection of set points and tighter operating tolerances. Reliable and extremely accurate "FS" style switches are widely used in critical O.E.M. applications. Factory calibrated set points, for increasing or decreasing pressure requirements, are available from .03 up to 1.0" W.C.

"AP" FIELD-ADJUSTABLE SET POINT

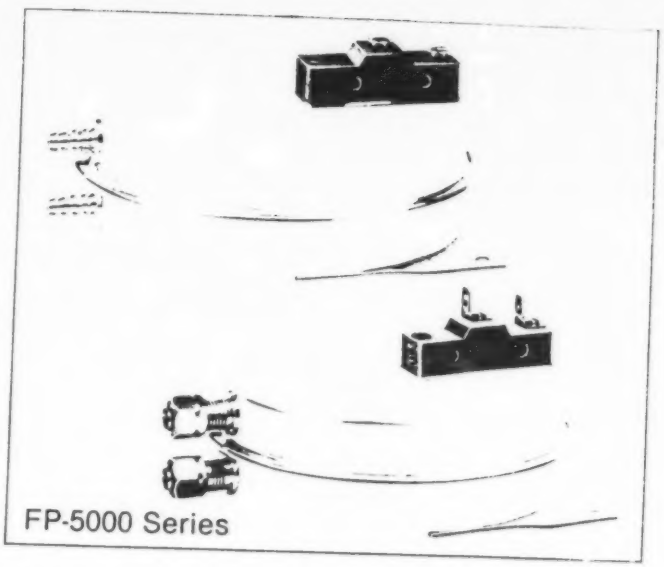
5000 series "AP" style switches offer extreme versatility for general purpose use in positive, negative or differential pressure sensing applications. Models are fully field-adjustable from .05 to 12.0" W.C. and with the option of *ultra-sensitivity* (adjustment range .03 to 12.0" W.C.) this product line stands alone in its field.

STANDARD FEATURES

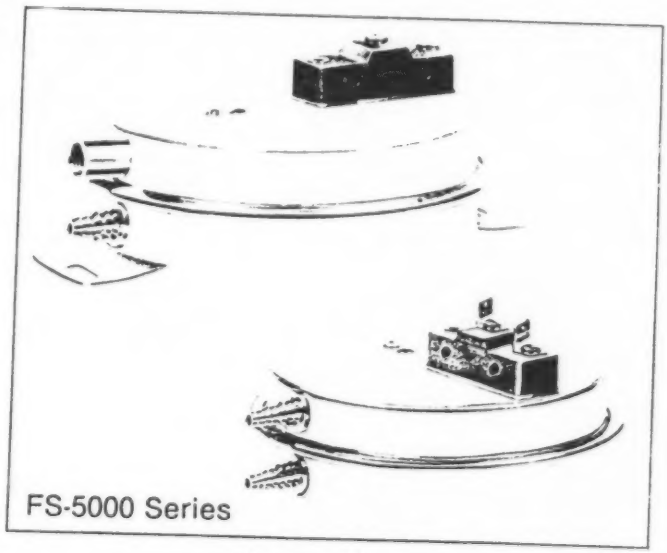
- Ultra low pressure sensitivity
- Rugged steel construction
- Zinc plated finish
- Electrical switches rated 15 amps; 300 VA pilot duty
- −40 to + 190° F. operating temperature range
- Conduit models with ground terminal provision
- UL & CSA approved for air or gas applications

OPTIONAL FEATURES

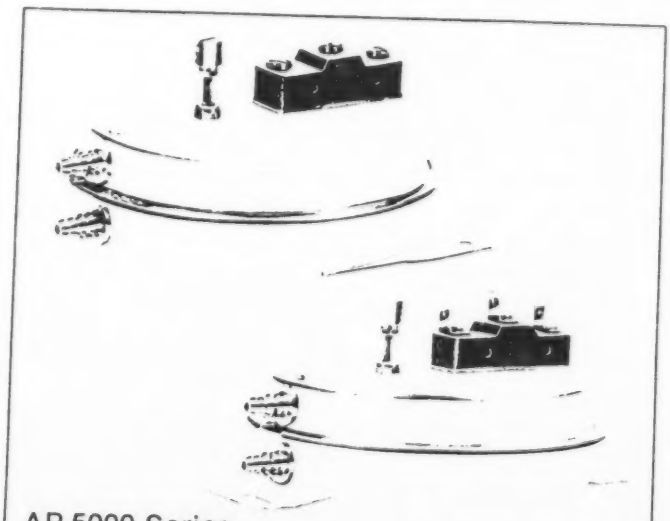
- Models built with or without wiring enclosures
- Visual set point indicator
- Visual on/off circuit indicating pilot lights
- Choice of SPDT or SPST snap action electrical switches
- Choice of electrical terminals ie, wire leads, screw terminal, 1/4" male quick connect
- Choice of having either a field-adjusted, factory calibrated, or fixed pressure set point
- Choice of 6 different sample line connectors
- Choice of 5 different mounting methods
- Salt spray protection
- Special weatherproof or explosion proof enclosure
- Air flow probes



FP-5000 Series



FS-5000 Series



AP-5000 Series

TRIDELTA INDUSTRIES, INC., 7350 CORPORATE BLVD., MENTOR, OH 44060 (216) 255-1080 TLX 980131 WDMR

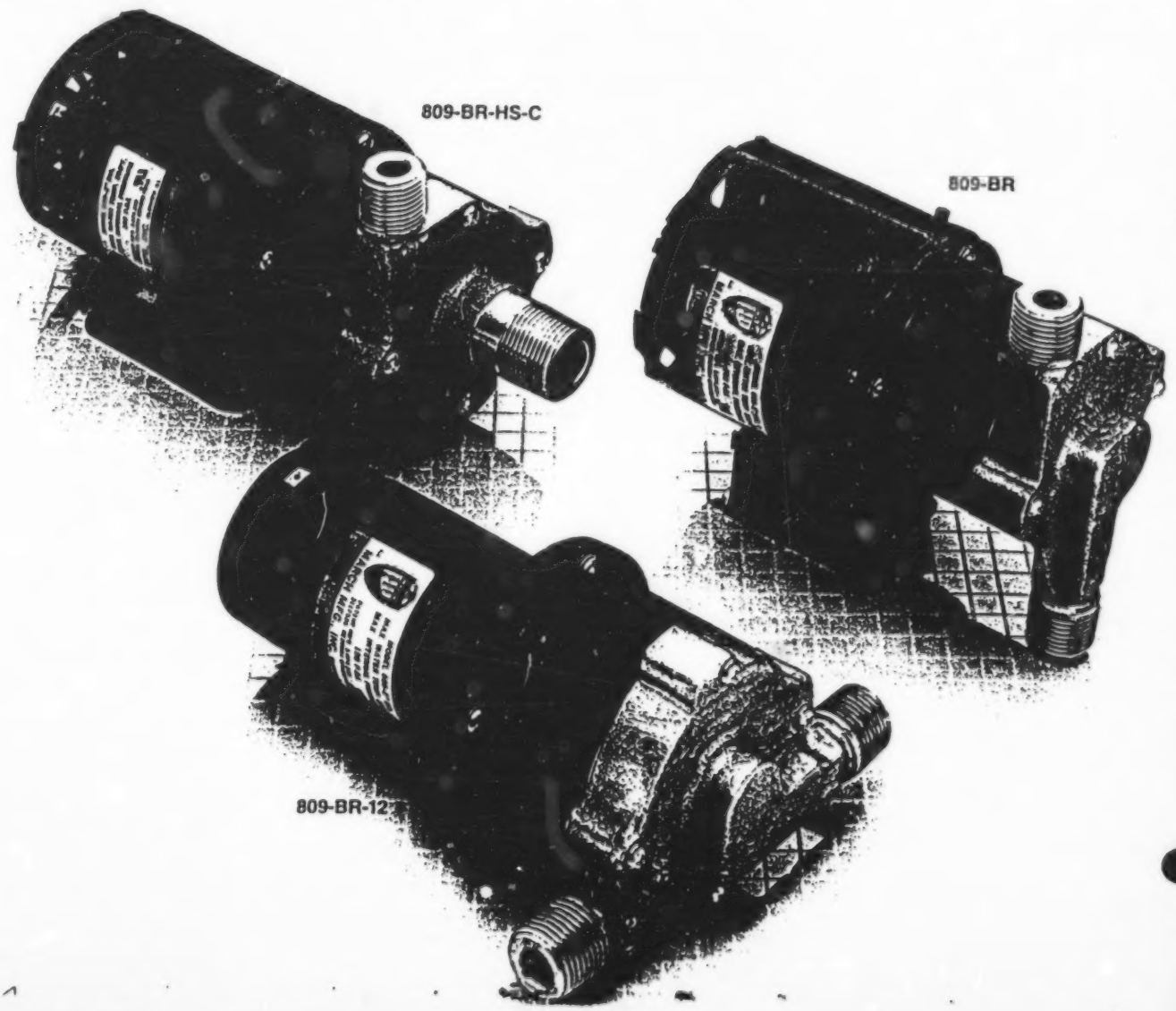
March circulating pumps with seal-less magnetic drive offer the ultimate in reliability for commercial, industrial, or domestic hot water systems. Their proven performance has established March as a leader in pioneering advancements for hydronic and solar systems... the only Magnetic Drive pump currently recommended by Dow Corning for their Syltherm™ 444 heat transfer liquid.

Standard models operate at up to 250° F. for water and up to 350° F. for hot oil with special designs available up to 500° F. for heat transfer fluids and pressures to 1000 PSI. These pump series are all U.L. recognized.

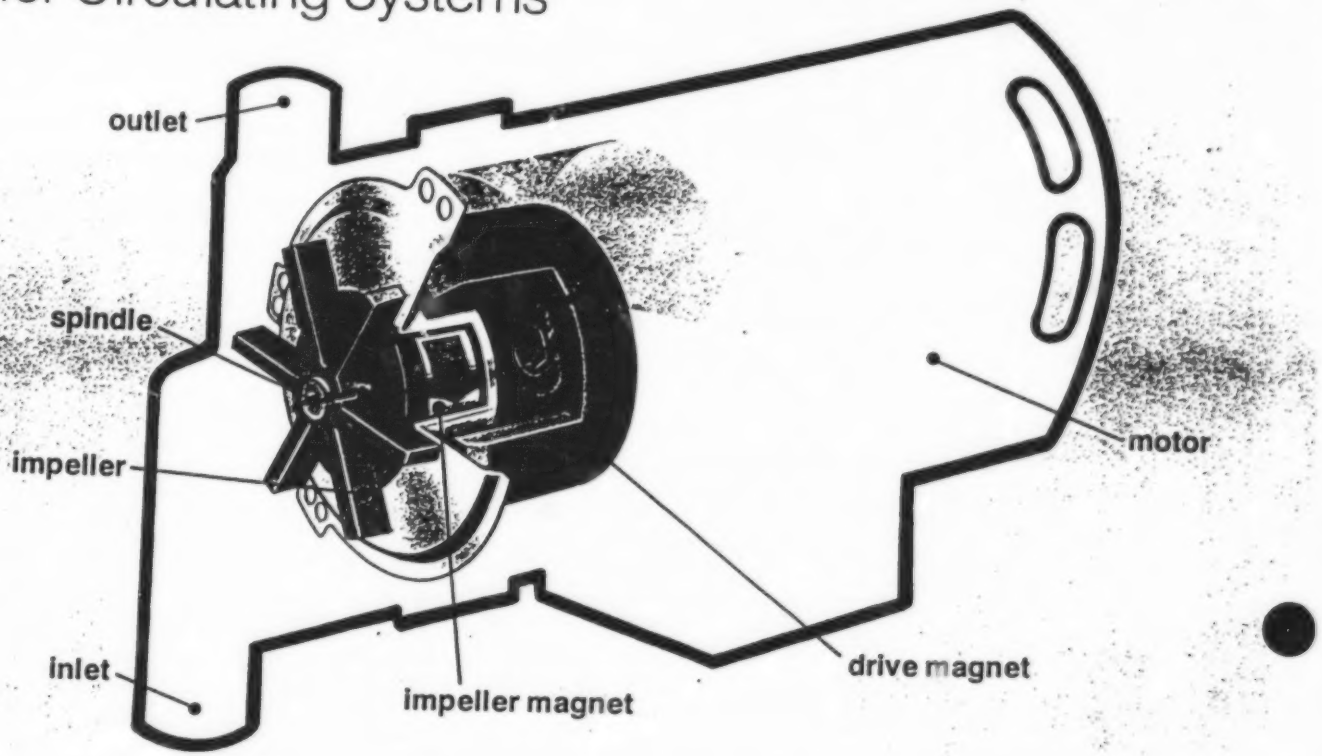
SERIES 809 & 815

Seal-less Magnetic Drive Pumps

These series are widely used in domestic, industrial and commercial hot water heating systems and hot water solar systems. Materials in addition to those shown are available.



Seal-Less
Magnetic Drive Pumps
for Circulating Systems



March circulating pumps with seal-less magnetic drive offer the ultimate in reliability for commercial or domestic hot water systems. Their proven performance has established March as a leader in pioneering advancements for hydronic and solar systems...the only Magnetic Drive pump currently recommended by Dow Corning for their Syltherm ™ 444 heat transfer liquid.

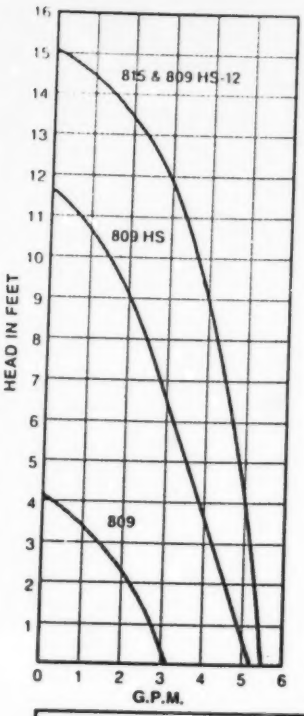
The magnetic drive advantage
March circulators with magnetic drive eliminate the multitude of problems related to shaft seal designs. Patented design has no seals, eliminates leakage and power-robbing friction. Full motor horsepower is transferred to pumping power with no loss due to seal friction, less amp draw. No maintenance due to seal wear or sediment jamming common to wet motor designs used in "canned" pumps.

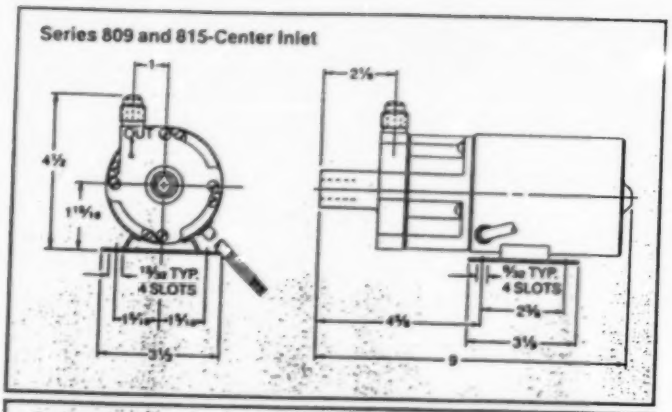
The air-cooled advantage
Motors are fan air-cooled to enable the circulation of high temperature water and heat transfer fluids without overheating. Standard models operate at up to 250°F. for water with special designs available up to 500°F. for heat transfer fluids and pressures to 1000 PSI. Cool running, semi-serviceable design also means that you can replace motors in minutes without having to drain the system.

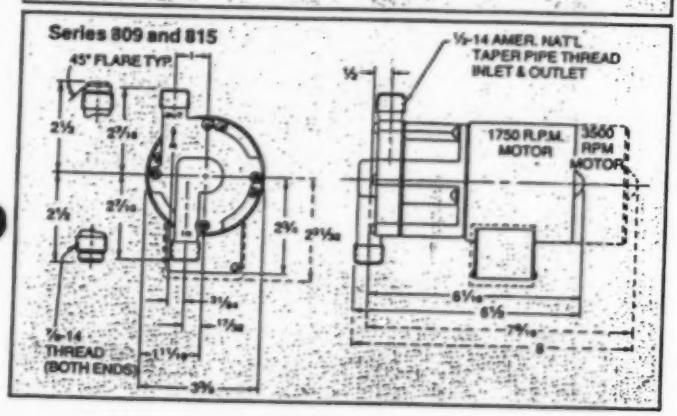
The quality advantage
Designed for continuous duty, March Circulators are constructed of first quality materials and components, built to the highest standards. Motors are cool running, sized for optimum performance and power consumption. Pump heads are available in optional cast iron, bronze, stainless steel or plastics, engineered to withstand peak pressures and temperatures. Built to stand up to corrosion and foreign matter. UL recognized components are used throughout. Most models are UL Recognized.

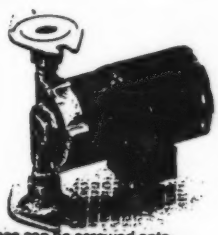
The March advantage
No other pump company offers so many sizes and high performance options to cover the full range of commercial and domestic hot water system applications. Ten standard models in the March line deliver 3 to 230 GPM and 0 to 112 feet of head pressure. Important features of the March line include 12 volt DC motors, dual pump heads, and provisions for vertical or horizontal installation. Altogether there are nearly 100 possibilities in one pre-engineered line. And March can custom design circulators to your specifications.

MARCH PUMPS









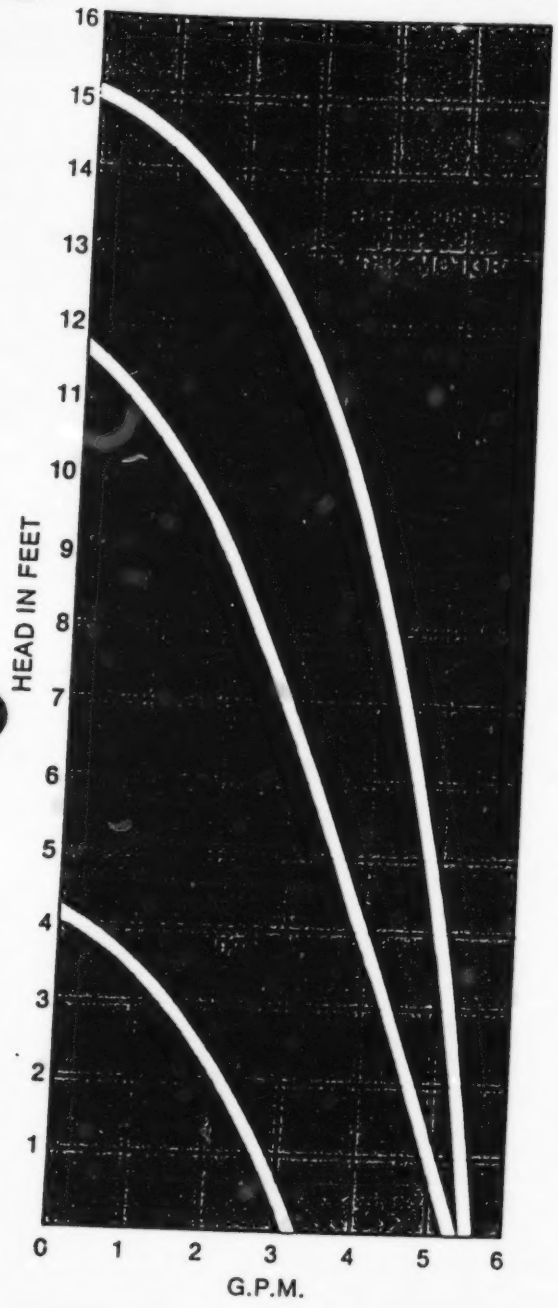
Flanges can be screwed onto the ½" inlet and outlet to make a flange style connection. Requires two flanges: P/N809-130-10. Bronze mating flanges available in ¾", 1", 1¼", 1½" sizes.

12 volt D.C. motors with replaceable brushes—24-volt available on special order.

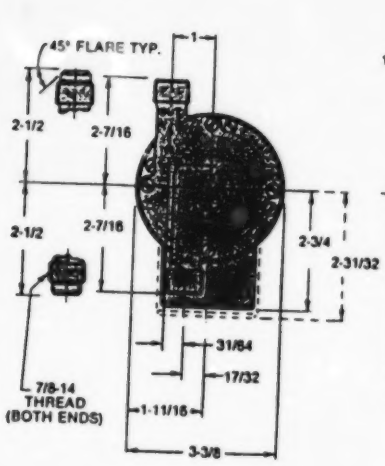
ELECTRIC MOTORS

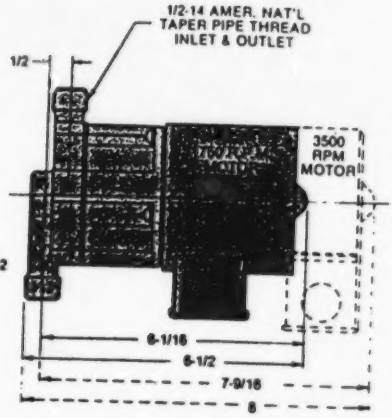
Model	Max. Flow GPM	Max. Head Ft.	Inlet* Cindicates Center Inlet	Outlet*	HP	RPM	Volts	PH	Hz	Watts	Amp	Motor Type	Electrical Connection	Materials* in Contact with Solution	Max. Int. Press PSI	Max. Liquid Temp.°F	Wt. Packed Lbs.
809-BR**	3.1	4.1	½"MPT	½"MPT								AC	Conduit Box		150	250	5
809-PL**	3.1	4.1	½"MPT	½"MPT								AC	Conduit Box		150	250	4
809-BR-C	3.1	4.1	C⅜"FPT	½"MPT	1/100	1700	115	1	60	30	0.4	AC	3 ft. SJO		150	250	6
809-BR-BB	3.1	4.1	½"MPT	½"MPT								AC/BB	Conduit Box		150	250	5
809-BR-BB-C	3.1	4.1	C⅜"FPT	½"MPT								AC/BB	3 ft. SJO		150	250	6
809-BR-24	3.1	4.1	½"MPT	½"MPT	1/100	1700	24	1	60	24	1.5	AC	3 ft. SJO	**PUMP HOUSING BR is Bronze. PL is Polysulfil Plastic. 316 Stainless Steel, Silicon rubber "O" ring, Ryton* and Teflon* Plastic impeller.	150	250	5
809-BR-12*	3.5	5.5	½"MPT	½"MPT	1/100	1900	12	—	DC	12	0.9	AC	Terminals		150	250	4½
809-BR-HS	5.3	11.6	½"MPT	½"MPT								AC	Conduit Box		150	250	5½
809-PL-HS	5.3	11.6	½"MPT	½"MPT								AC	Conduit Box		150	250	5
809-BR-HS-C	5.3	11.6	C⅜"FPT	½"MPT	1/25	3400	115	1	60	90	1.2	AC	3 ft. SJO		150	250	6½
809-BR-HS-BB	5.3	11.6	½"MPT	½"MPT								AC/BB	Conduit Box		150	250	5½
809-BR-HS-BB-C	5.3	11.6	C⅜"FPT	½"MPT								AC/BB	3 ft. SJO		150	250	6½
809-BR-HS-12*	5.5	15	½"MPT	½"MPT	1/35	3600	12	—	DC	32	2.7	AC	Terminals		150	250	4½
815-BR	5.5	15	½"MPT	½"MPT								AC	Conduit Box		150	250	5½
815-PL	5.5	15	½"MPT	½"MPT								AC	Conduit Box		150	250	4½
815-BR-C	5.5	15	C⅜"FPT	½"MPT	1/25	3400	115	1	60	105	1.3	AC	3 ft. SJO		150	250	6
815-BR-BB	5.5	15	½"MPT	½"MPT								AC/BB	Conduit Box		150	250	5½
815-BR-BB-C	5.5	15	C⅜"FPT	½"MPT								AC/BB	3 ft. SJO		150	250	6

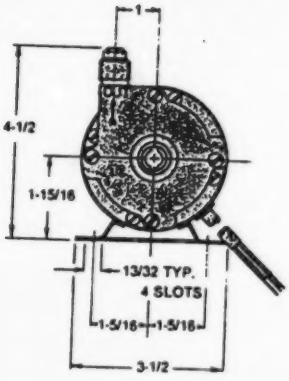
* Flare style and solder style connections available on special order
* Other materials available on special order
* Brush life is a minimum of 10,000 hours
* Brush life is a minimum of 7,500 hours

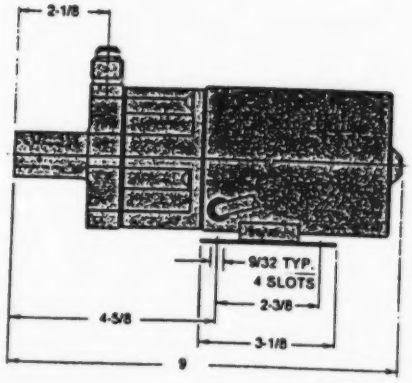


MODEL NO. 809 & 809 HS



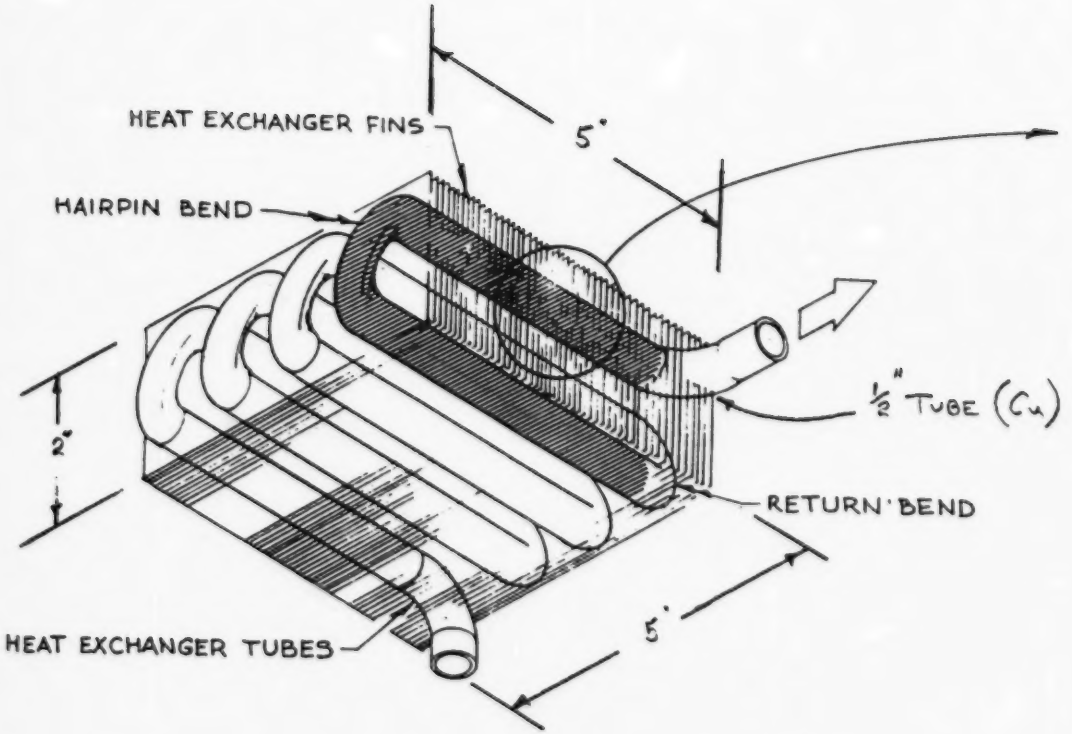




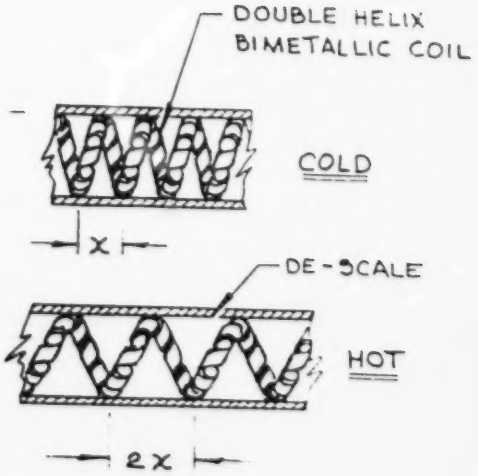


STANDARD MOTORS HAVE SLEEVE BEARINGS. BALL BEARING MOTORS ARE AVAILABLE.

MODEL	GPM	FEET OF HEAD	MAX. PSI DEVELOPED	H.P.	RPM	VOLTS	HZ	WATTS	AMPS	PUMP WT.
809	3.1	4.1	1.8	1/100	1600	115 A.C.	60	30	0.4	4-1/2 lbs.
	3.1	4.1	1.8		1600	24 A.C.	60	24	1.5	
	3.1	4.1	1.8		1600	12 D.C.		12	0.9	
809 HS	5.3	11.6	5.0	1/25	3400	115 A.C.	60	90	1.2	5-1/2 lbs.
	5.5	15	6.53		3600	12 D.C.		40	3.3	
815	5.5	15	6.53	1/25	3400	115 A.C.	60	105	1.3	5-1/2 lbs.



INDICATES EXTENT OF BIMETALLIC COIL IN TUBE



DETAIL
- LARGE SCALE -
SHOWING ACTION OF COIL IN TUBE

NOTES:

① 1 COIL TO HAVE ALUMINUM FINS ② 12 FINS [illegible] WITH TEFLON COATING.

③ 1 COIL TO HAVE [illegible] FINS ④ 8 FINS [illegible]

BOHN

Bohn Heat Transfer Division
Gulf + Western (Canada) Ltd.
(416) 336-1952

OEM COIL CONFIGURATION DATA SHEET

CUSTOMER _____ DATE _____ BY _____

COIL: Evaporator ☐ Condenser ☐

Coil Duty _____

Fin, Type Cu Thickness _____

Tube Dia. 5/16 ☐ 3/8 ☐ 1/2 ☐ 5/8 ☐

Tube Mat'l. Cu Thickness _____

Return Bend Thickness _____

Tubes High 4 Centers 1"/4

Rows Deep 2 Centers 1"/4

Fins Per Inch 5

Fin Depth _____

Fin Height _____

Fin Length _____

C.S.A. APPROVED

Bursting Pressure _____

Die No. _____

HEADER: Mat'l. _____ Dia. _____

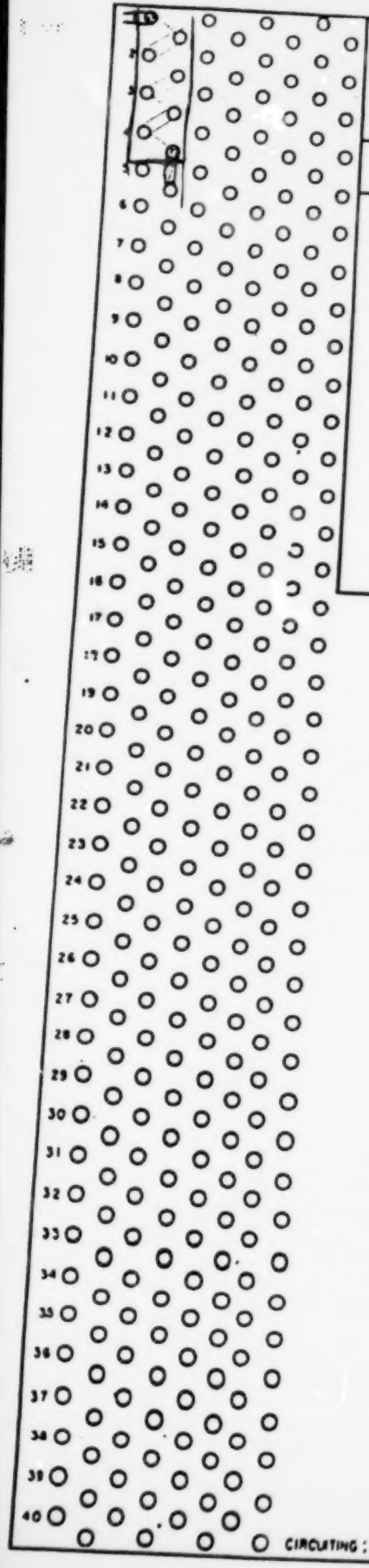
END PLATES: Mat'l. _____

SIDE PLATES: Mat'l. _____

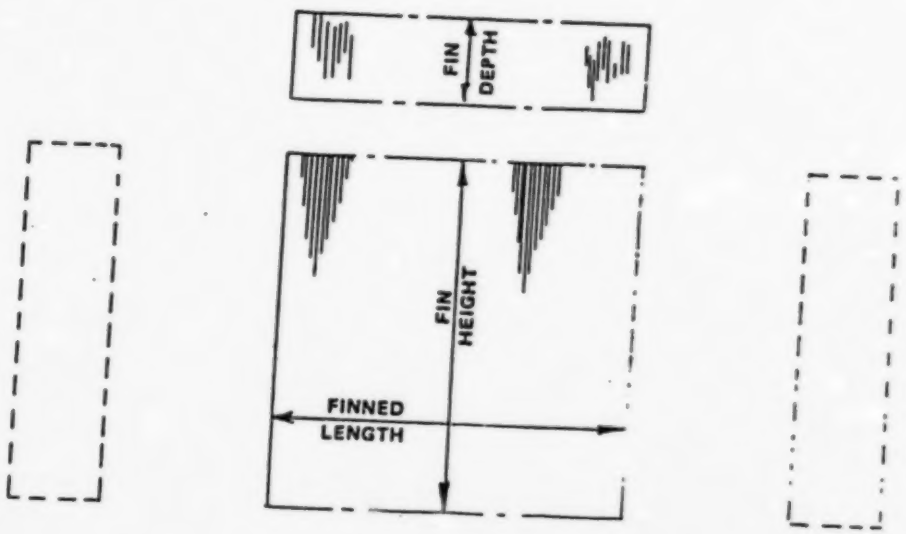
FIN SURFACE: Corr. ☐ Flat ☐

FIN EDGES: Straight ☐ Rippled ☐

Coil Type _____



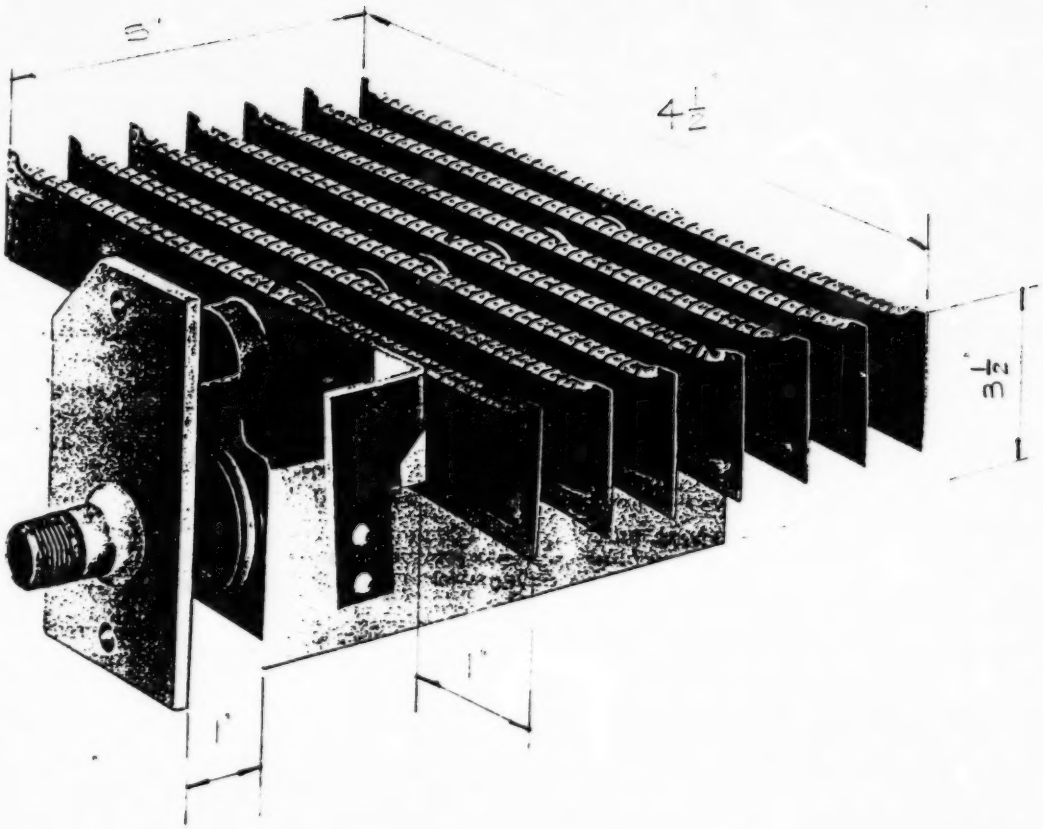
○ CIRCULATING ; STAGG. PATTERN



Customer Part No. _____

Dwg. No. _____

FORM NO. 30-171.RC



SCALE -		
MAT'L - SIZE -	QTY.	D W H USED ON

ENEROIL RESEARCH LTD.
Concord, Ontario L4K 1L6

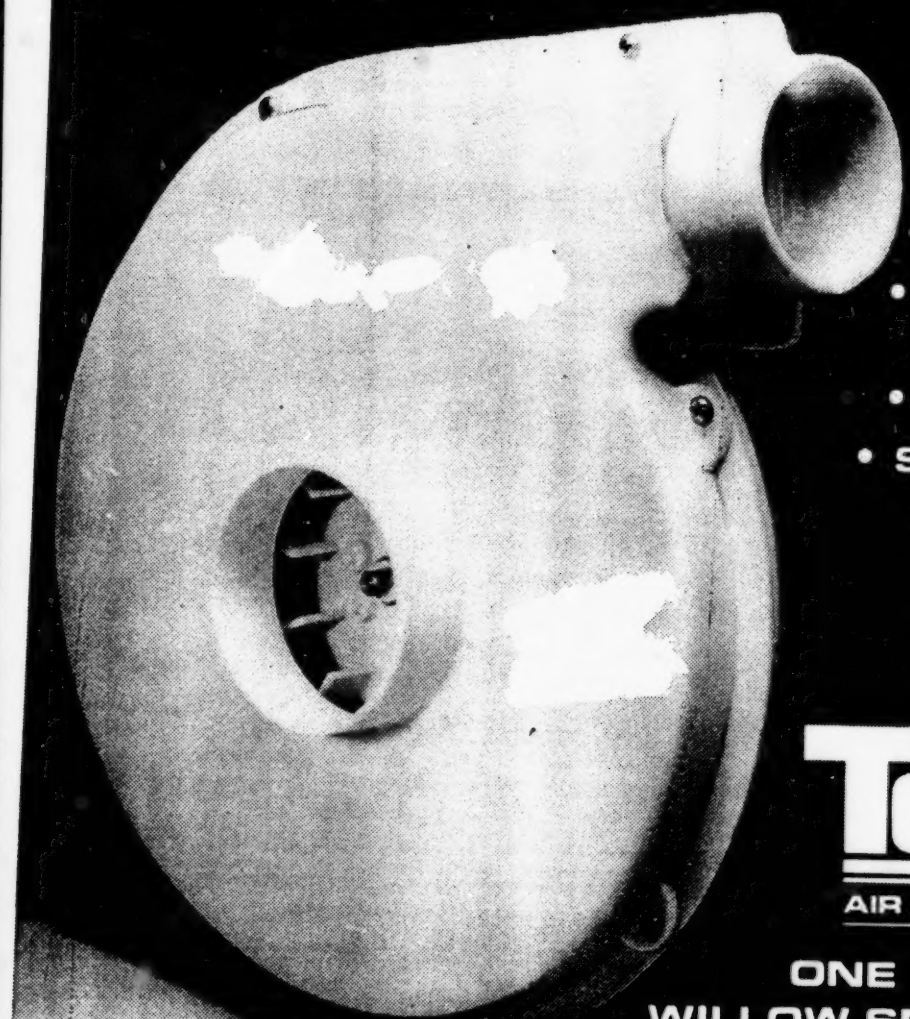
PROTOTYPE BURNER

REV.	REVISION	BY	DATE	E.C.R.
D				
C				
B				
A				

DR'N BY	DATE	DRAWING NUMBER	REV.
CANDE	5.10.6	51372 A	

CH'D BY | APP'D BY

HIGH EFFICIENCY BLOWERS



- All plastic
- Designed to handle flue gases
- High temp models
- Optional discharge designs
- Variable inlet sizes
- Static pressures up to 4.0" W. G.
- Several Sizes Currently Tooled

TecAir INC

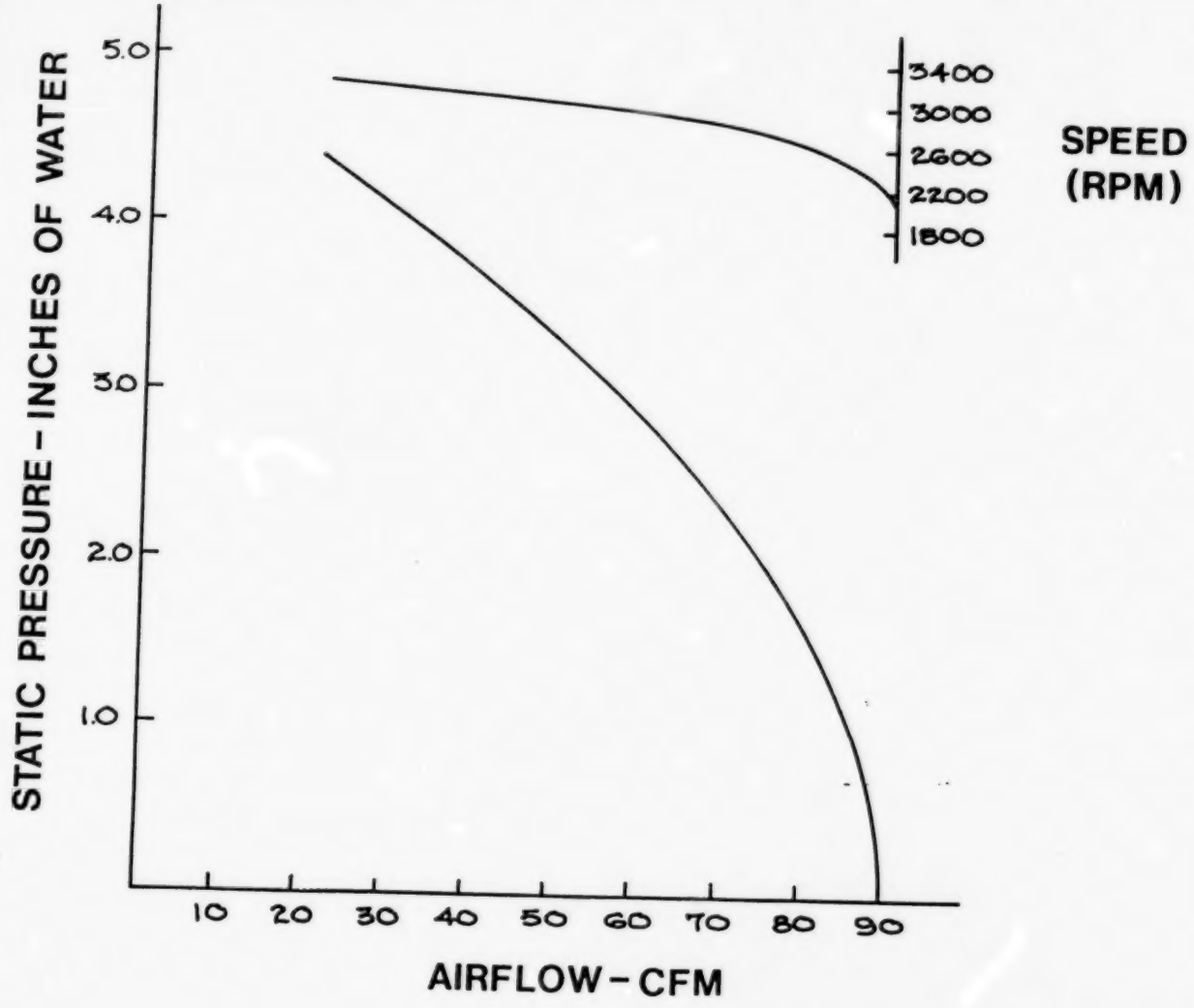
AIR MOVEMENT SPECIALISTS

ONE TEC AIR AVENUE
WILLOW SPRINGS, IL 60480
(312) 839-1400

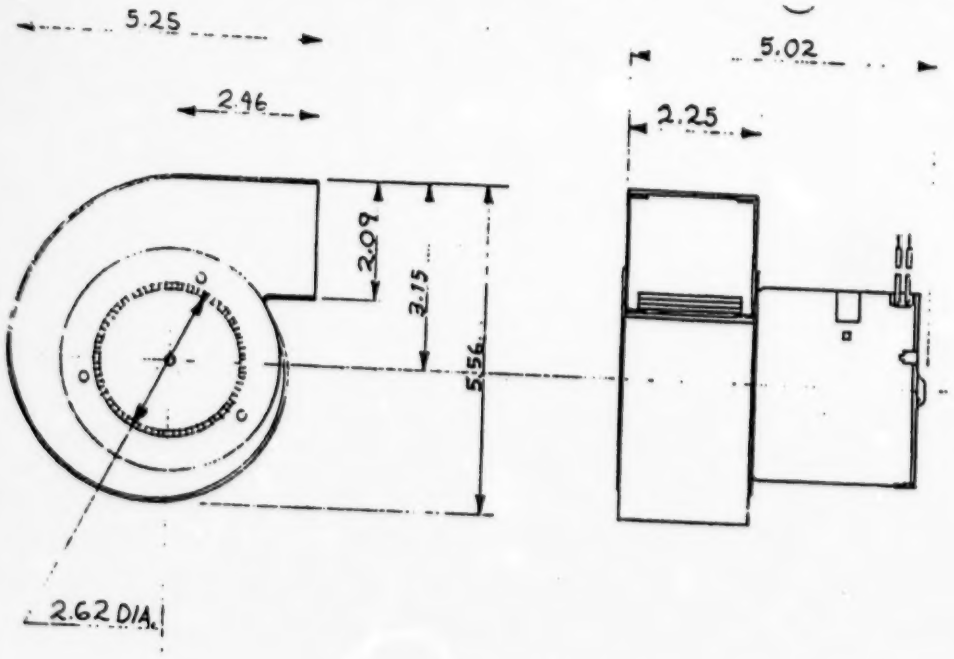
TecAir INC
AIR MOVEMENT SPECIALISTS

One Tec Air Avenue
Willow Springs, IL 60480
(312) 839-1400

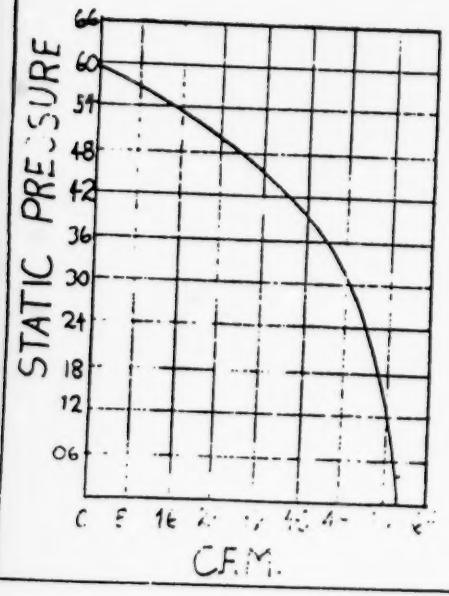
MODEL – BLOWER ASS'Y.
*BA05117E



TOLERANCES (EXCEPT AS NOTED)	TEC AIR Inc.		WILLOW SPRINGS ILLINOIS 60480
DECIMAL ± .005		SCALE NL	DRAWN BY J.F.D.
			APPROVED BY DM
FRACTIONAL ± 1/64	TITLE *BA05117E PERFORMANCE		
ANGULAR ± 1/2°	DATE 3.31.88	DRAWING NUMBER BA 5117	



REVISIONS



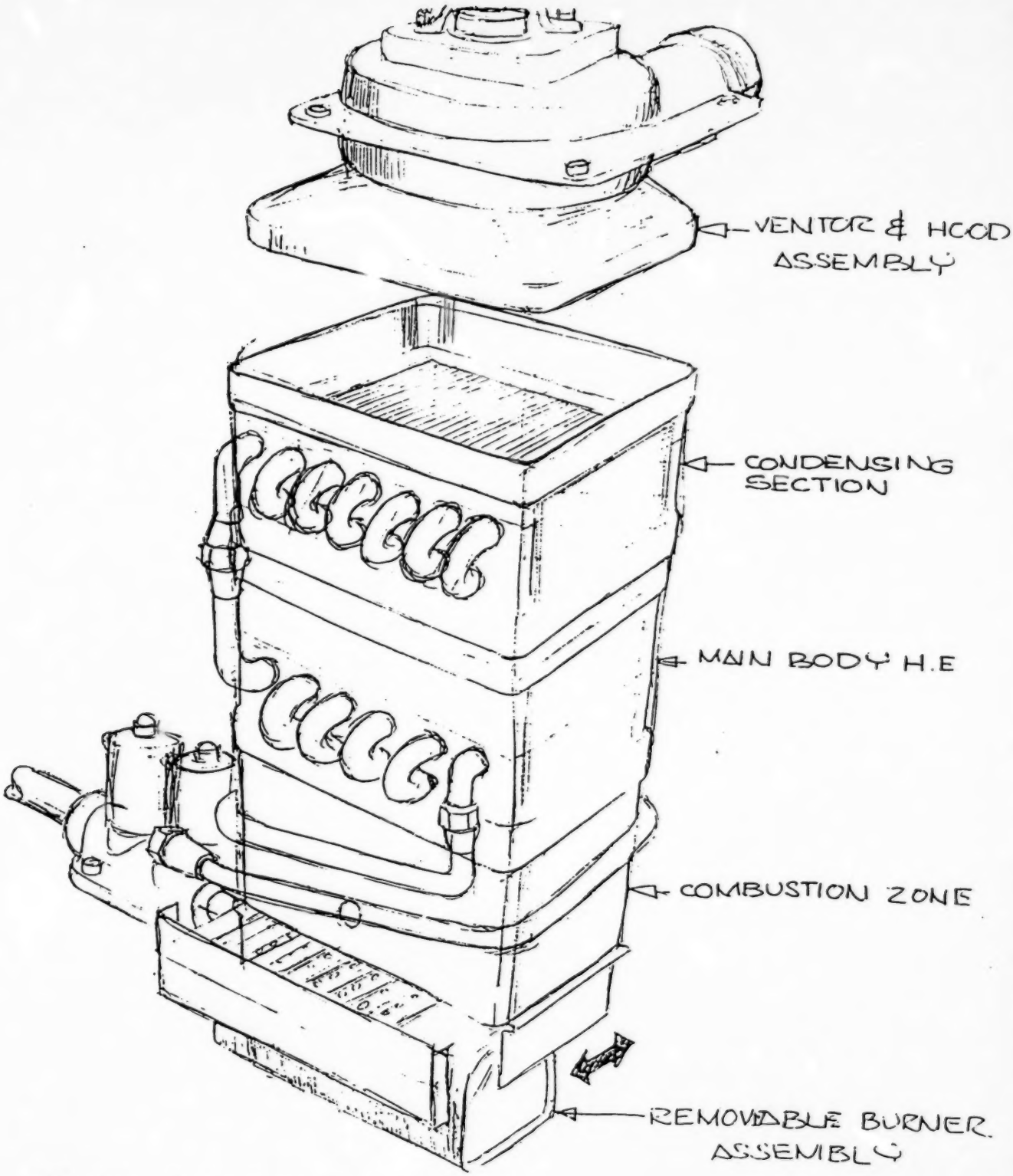
VOLTS	HZ.	THERM. PROT.	R.P.M.	WATTS	AMPS	H.P.
120	60/50	AUTO	3030	36	0.42	1/125

ONE SAMPLE
FORTHCOMING
JULY 31

T.F.

Hi-Tech, inc.
3204 16TH ST., ZION, ILL.

PART NAME 60 C.F.M. BLOWER	
SCALE 1/3" = 1"	DRAWN H. ROBISON
MAT'L	DATE 7/13/77
UNLESS OTHERWISE NOTED TOLERANCES ON FRACTIONS ± TOLERANCES ON DECIMALS ± .02	APPROVED
	DATE
PART NUMBER	REV. NO.



R.H ASSEMBLY W/H. 1+3